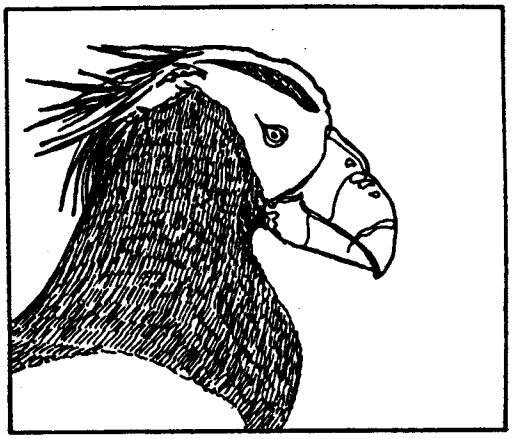
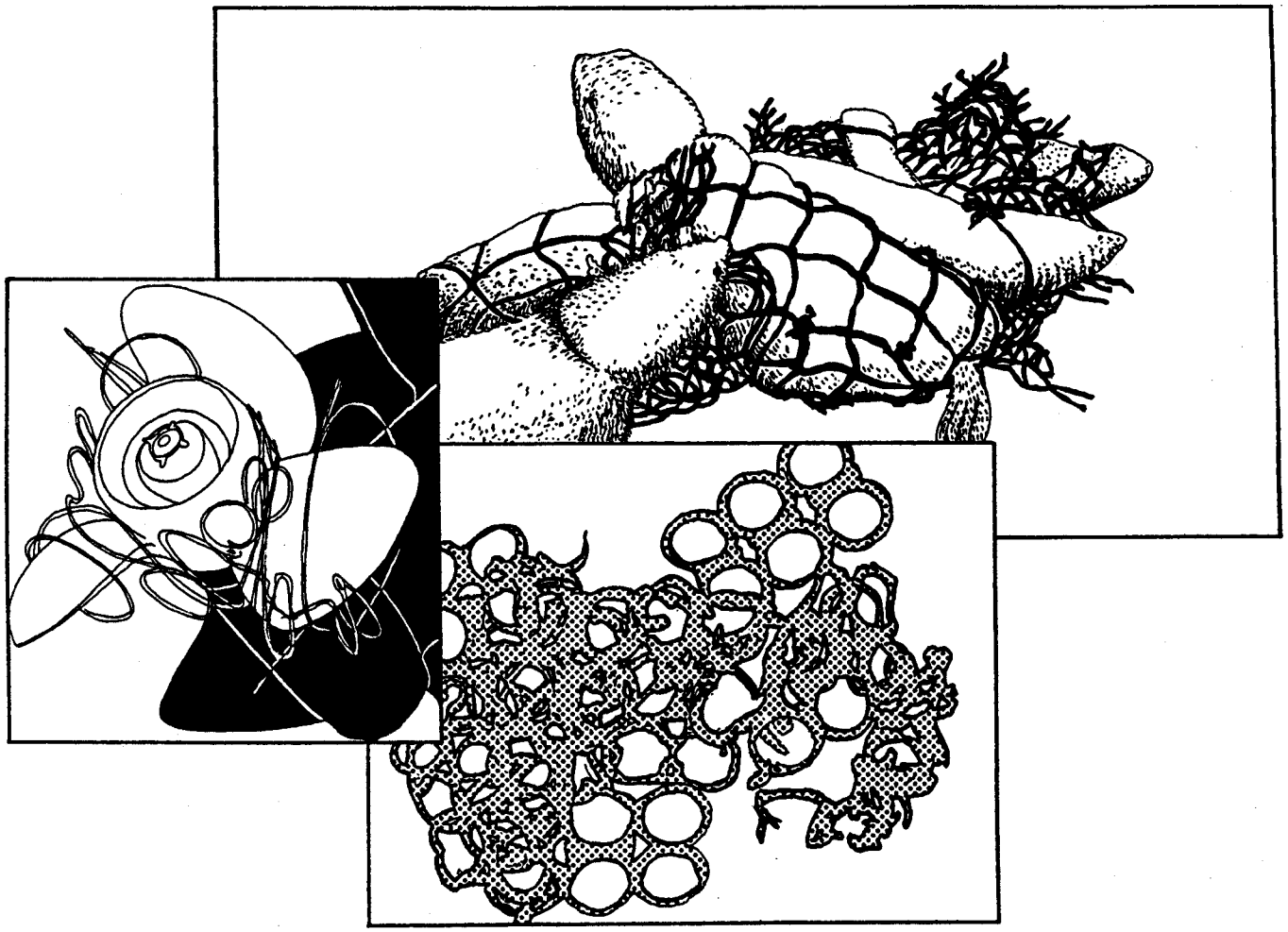


POSTER PRESENTATIONS



ANIMALS AS LITTER VICTIMS AT THE GERMAN NORTH SEA COAST

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ABSTRACT

Over a distance of 65 km at 12 beaches of the German North Sea coast, 64 entangled vertebrates belonging to 14 species (mainly gulls, gannets, guillemots) were found dead from August 1983 to April 1988.

On the island of Helgoland, furthermore, 53 living seabirds belonging to 11 species (most gannets) were observed as entangled with remains of ships' litter. In at least 46 cases, plastic material was involved, so that the chance of survival of the animals must be rated as very low.

The numbers quoted must be considered as minimums, since not all animals affected or entangled with litter reached the shore or were found there. Also those animals which died as a result of litter ingestion are not listed.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

MARINE DEBRIS AND EPIPELAGIC FISHES

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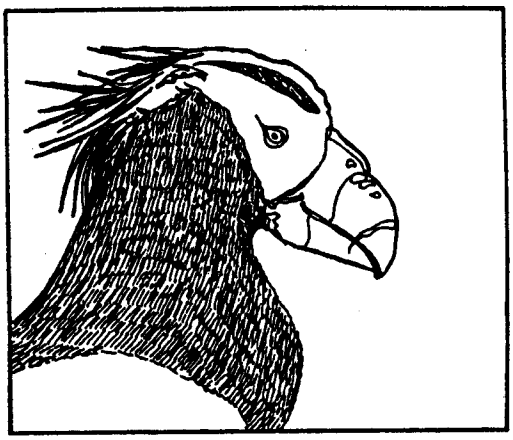
ABSTRACT

Two species of epipelagic fish caught in 1987 and 1988 by commercial fishing vessels operating in the vicinity of the Hawaiian Archipelago display the impacts of marine debris. The first specimen is a male mahimahi, *Coryphaena hippurus*, 77.5 cm total length and weighing 2.06 kg. Captured during albacore trolling operations, the mahimahi had monofilament net fragments attached to its gills and opercular area. The other instance involves a swordfish, *Xiphias gladius*, measuring approximately 140 cm total length and weighing 10 kg caught during tuna longlining operations. A rubber band cut approximately 3 cm deep into its caudal peduncle; otherwise, the swordfish appeared normal. Presented are photographs of both specimens and speculations as to the possible origins of the impacting debris.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.



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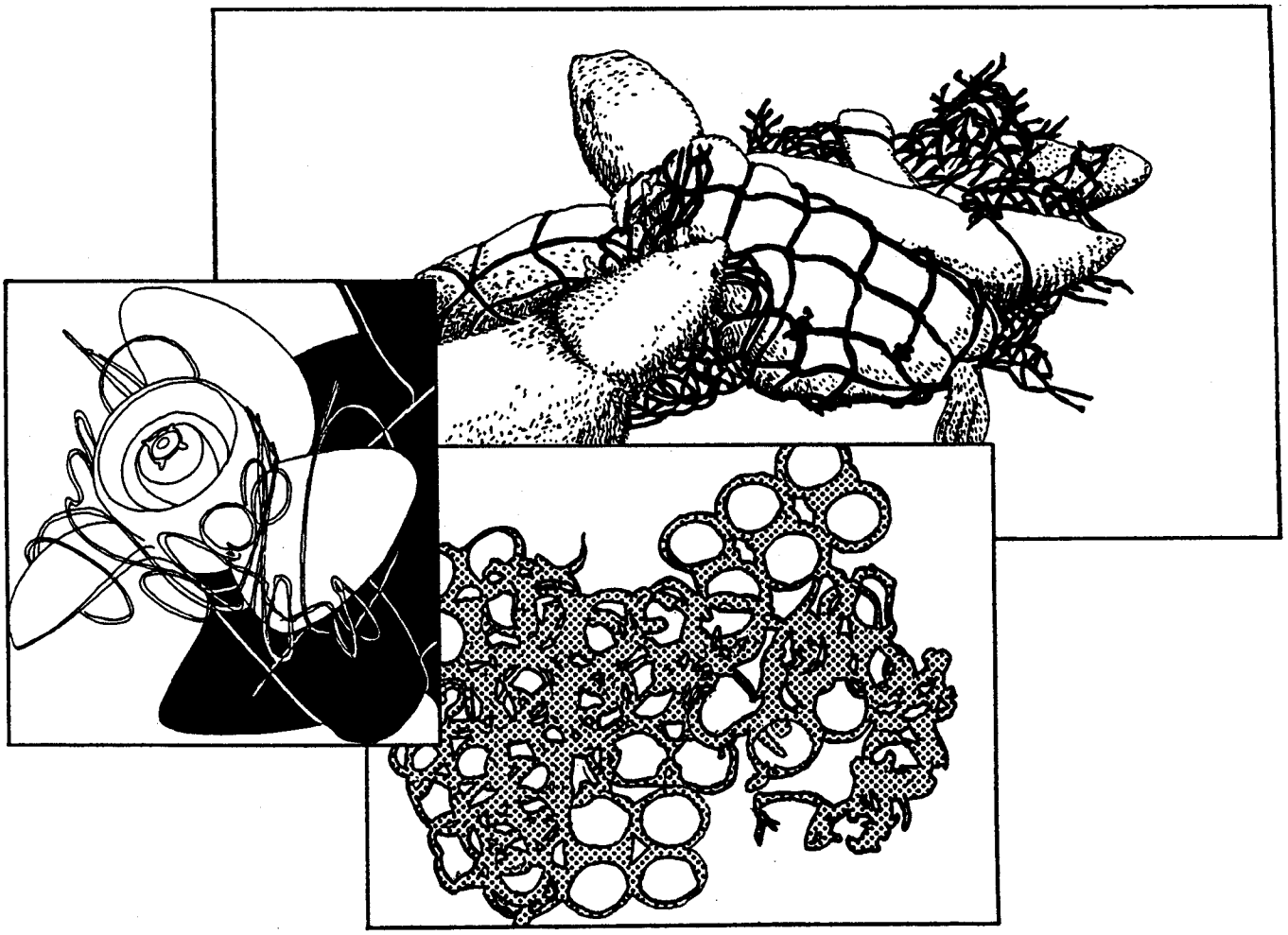

PORTRAIT OF A BARRIER ISLAND BEACH

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ABSTRACT

Spanning a period of 11 years, 1,800 transects have been made along a 12-km stretch of beach on Mustang Island, Texas, to observe the seasonal and long-term changes to this barrier island beach bordering the northwest Gulf of Mexico. Documented in the ongoing study are bird populations, human disturbance, beach morphology, local oceanographic and weather conditions, stranded marine mammals, turtles, birds, oil spills, fish kills, effects of severe weather, and occurrence of marine debris and litter. This talk illustrates visually the tremendous impact, both aesthetic and as a danger to wildlife, of marine debris and increasing human usage on this otherwise beautiful beach. Also illustrated are several environmental and other factors that complicate efforts to understand the seasonal and long-term trends in the distribution of marine debris.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

U.S. OIL INDUSTRY EFFORTS IN ADDRESSING BEACH DEBRIS PROBLEM

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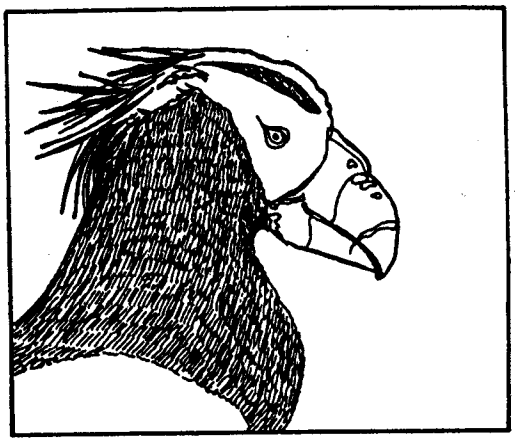
ABSTRACT

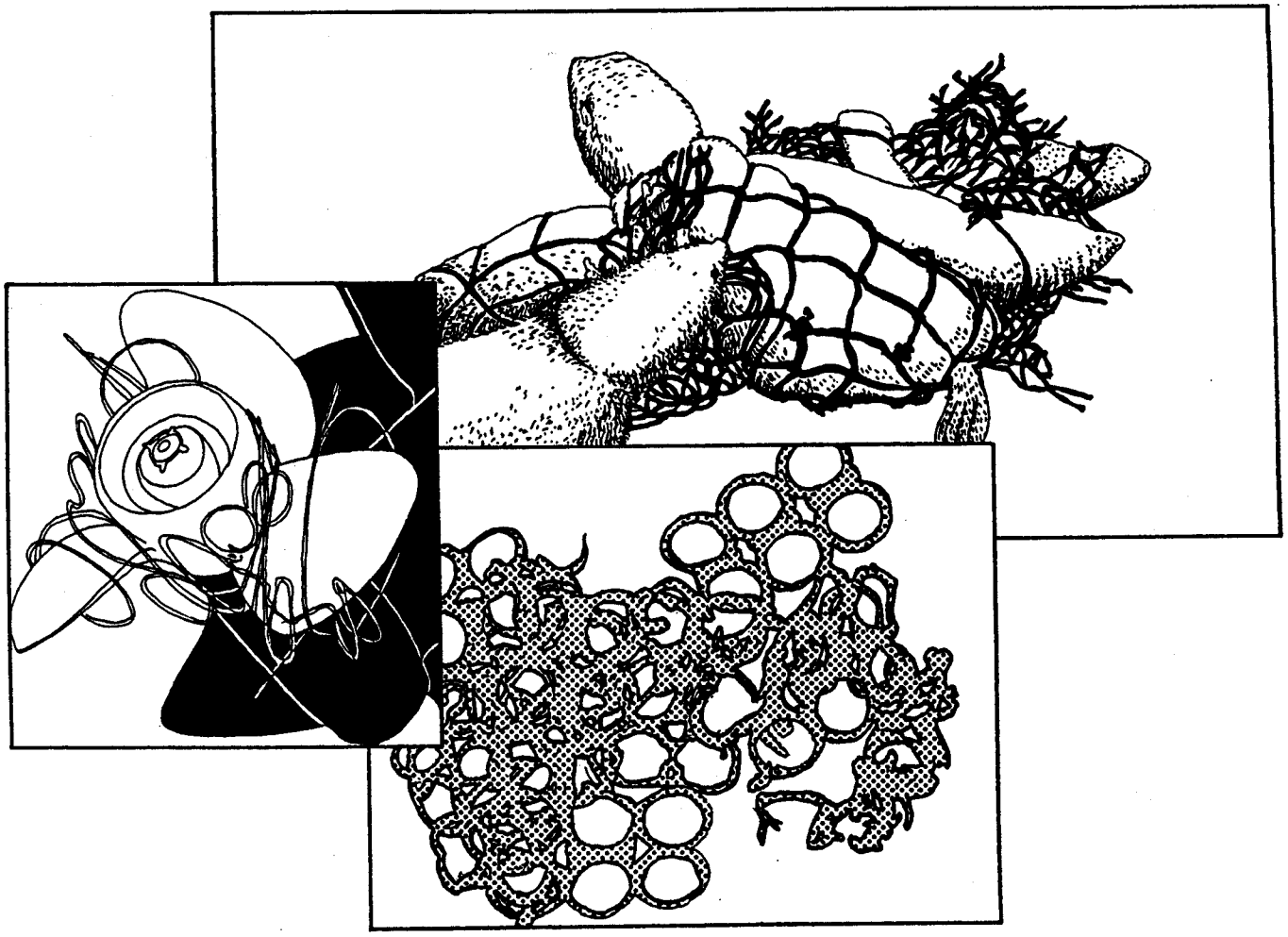
The United States Gulf of Mexico offshore oil and gas industry has, over the past 2 to 3 years, embarked on an industry-wide effort to eliminate its contribution to marine debris. Beach debris surveys on gulf coast beaches previously identified a significant percentage of the debris originating from offshore exploration and production operations. As regulations which prohibited the discharge of trash from these facilities were already in place, it was thought that carelessness and possibly ignorance were involved.

It was evident that education would be the best way to approach this problem. This presentation will focus on a 12-min video developed by the offshore operators' committee, along with some individual efforts undertaken by companies, which we have used in the education process.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.



WORKING GROUP REPORTS



REPORT OF THE WORKING GROUP ON METHODS TO ASSESS THE AMOUNT AND TYPES OF MARINE DEBRIS

(Christine A. Ribic, Chair)

INFORMATION NEEDS AND METHODOLOGIES

For the determination of the amount and types of marine debris, the working group distinguished between two types of studies: baseline, studies with low sampling frequency made over large geographic areas; and assessment, studies of a more limited area and having more intensive sampling effort over time. Baseline studies describe existing marine debris and seek to identify the magnitude of a problem. Assessments study the level of pollution.

The group considered various methodologies now in place for determining the amount of debris in the ocean (nearshore, open ocean, and bottom) and on beaches. They agreed that the beach survey is appropriate for assessment studies on a large scale. For limited-scale studies, dedicated surveys using visual observations and neuston tows in nearshore areas (e.g., bays, harbors, and estuaries) or limited ocean areas such as offshore dumping areas can be used for assessment.

Table 1 summarizes the current utility of survey techniques. Use of aircraft, while experimental, is feasible for baseline studies. Techniques to study bottom debris are needed; currently bottom debris studies are categorized as baseline.

Figure 1 is a proposed outline of the stages of a marine debris pollution assessment plan.

GEOGRAPHIC AREAS

The vastness of the oceans makes it necessary to select areas of interest for more intensive studies. On an international level, the working group suggested MARPOL special areas as appropriate geographical areas for more intensive study. On a national or a regional level, special areas of local interest must be developed. Examples of national level areas were the Pribilof Islands, because of the impact of debris on northern fur seals (United States), and national marine sanctuaries (United States). A regional area of interest cited was the Caribbean. Freshwater systems, including estuaries, were not discussed by the working group for lack of time.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Table 1.--Summary of survey techniques.

Survey techniques	Type of study	
	Baseline	Assessment
Nearshore/open ocean		
Surface debris:		
Visual observation (strip/line transect)	Platforms of opportunity	Dedicated surveys in well-defined areas of importance
Neuston nets	Oceanographic surveys	Dedicated surveys in well-defined areas of importance
Photography	Aircraft/helicopter (limited to large debris items)	
Bottom debris:	Limited to certain types of communities	
Survey of fishermen	Questionnaire (limited to certain types of debris)	
Bottom trawl	Limited to certain types of communities	
Remote operating vehicles	Expensive to use	
Beach surveys	Volunteer efforts (educational/ public relations)	Planned surveys Estimates of amounts on beaches--random sampling Changes over time--same beach or transect
	Low-flying aircraft	

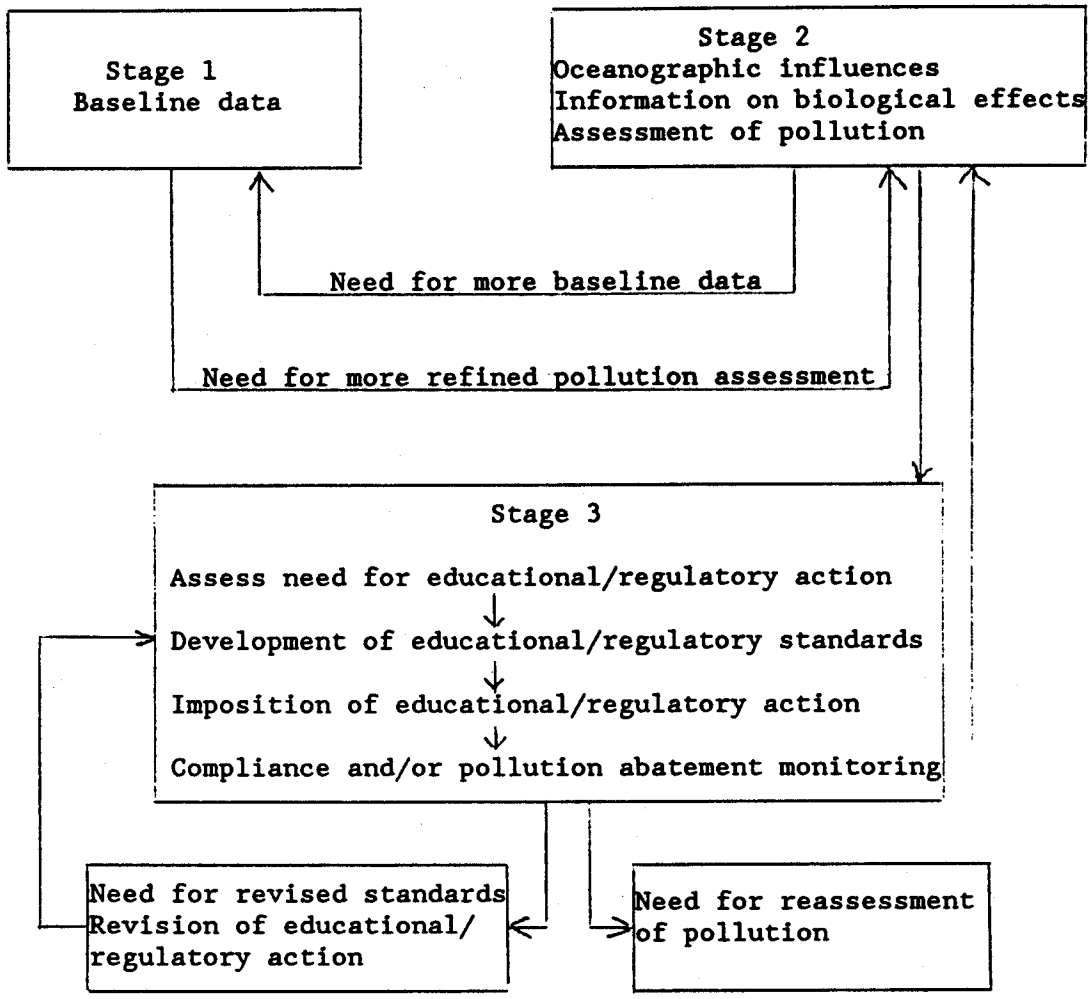


Figure 1.--Components of a marine debris assessment plan (after G. Kullenberg et al. (1986) Mar. Pollut. Bull. 17:341).

Floating Debris at Sea

At sea, counts of floating debris are made using platforms of opportunity and dedicated surveys.

Visual observation from a viewing platform such as the flying bridge of a vessel is used when counting large debris. Most studies employ a strip transect method and count all debris sighted within a certain distance of the ship, using the glare-free side of the ship for observation. The width of the strip depends on the height of the viewing platform as well as on survey conditions (e.g., Beaufort sea state), and may change during the survey. All debris in the strip is assumed to be sighted. No one has done work on the probability of sighting different debris objects, and there are potential size and color biases that need to be evaluated. The length of a single transect varies as does final total transect length. The variable considered is usually a density estimate, number per square

kilometer or number per square nautical mile. The group recommended that two or three observers be employed in the survey. A single observer should use a strip width of 25 m or less. Calibration runs were recommended to estimate strip width, and experiments were recommended to investigate color and size biases and the probabilities of sighting different debris types.

There has been limited line transect work, but no formal analysis has been published. Problems persist with inaccuracies in the data, notably in the accurate determination of the distance of debris perpendicular to the ship. When accurate distance measurements can be made, the working group recommended the use of the line transect.

Neuston tows (necessarily strip transects) appear to be the most extensively used method for the study of particulate plastic and tar balls. The group agreed on the usefulness of such tows when made from dedicated survey vessels, but questioned whether neuston tows could be made successfully using platforms of opportunity. They require certain speeds--some devices can be used at speeds of only 3 kn or less; others at up to 7 kn--and the group questioned a captain's willingness to slow the ship down sufficiently to accommodate the towing device. Important to the success of a neuston tow is the estimate of time actually towing, or sweep efficiency.

The working group noted the possibility of using low-flying aircraft to survey nearshore areas for debris.

Debris on the Sea Floor

Little is known about bottom debris. Bottom trawls may be used from either dedicated survey vessels or platforms of opportunity to sample sea floor debris. The working group discussed bottom trawls for sampling debris, noting that this area has seen little work. They agreed that composition of debris is measurable using bottom trawl gear, but estimates of density are thought to be questionable.

Remote Operating Vehicles (ROV) were mentioned as a possible sampling tool, but it was agreed that this approach is too expensive for widespread use. Bottom drifter studies were also mentioned.

A potential source of information are fishermen whose gear has become entangled in sea floor debris. The working group recommended the development of a survey form to collect bottom debris from fishermen. This could be a starting point for collecting baseline information on bottom debris.

Debris on Beaches

Beach debris surveys can be carried out in designed or in volunteer programs. Standardization of beach surveys has been attempted for Alaskan beaches and English beaches, with the major difference being the sampling unit. In Alaska the sampling unit is the entire beach (at least 1 km in length). The sampling unit for the English beach is one transect per beach. Based on the working group discussion, it appears that the difference in sampling strategy stems from the types of debris found on the beaches. Entire Alaska beaches have to be surveyed in order to count the trawl web

that dominates the debris. In England, where most of the debris is plastic, transects are used because there is too much debris to count.

To avoid as much as possible counting debris that has originated on land, both approaches emphasize surveying beaches that are away from urban areas and have little recreational use. Beaches of sand and small gravel substrates with moderate slope were selected because they tend to collect debris. In England back beach areas were included; in Alaska they were not. Alaskan beaches facing the open ocean were used. Beaches with complicated topographic features such as partly sheltering reefs should be avoided, as should beaches known to be cleaned periodically. Other variables to consider are prevailing winds and accessibility.

If the intent of the study is to estimate the amount of debris on beaches in a given area, then random beach selection is important. In England a two-stage stratified random sampling scheme was used successfully. To detect changes over time, the majority of the group felt that selected beaches should be sampled repeatedly over time. The kind of change expected should be predicted, an appropriate variable defined to measure that change, and data collected to support or refute the prediction.

For baseline and some assessment studies, total amount, weight, and composition of the debris should be measured. Volume measurements were considered, but the working group felt that they would not be possible in all situations. For studies of changes in debris type over time, there was general agreement that the type of debris would determine whether changes in total amount or changes in composition were of more importance. In Alaska it was considered important to detect a change in the amount of trawl web. In England, composition and age structure of plastic containers were of prime interest. The important point in addressing the question of change over time is to define a variable of interest that can be measured.

For assessment studies, more work is needed to understand beach debris dynamics--for example, local currents and sinks for the debris as well as debris sources.

A suggestion was made to utilize low-flying aircraft, as some current surveys in Alaska are doing.

Debris Emanating From Land

The working group disagreed about the ease of distinguishing debris of land origin from debris originating on board ship. The accuracy of identification may vary from area to area. After some time in the water, debris items lose any paper labels and may acquire encrusting biota. Some items obviously originating on land may include plant seeds.

CATEGORIZATION OF DEBRIS

One suggestion was to categorize debris sizes as follows:

Mega - >2-3 cm
Macro - 5 mm to 2-3 cm

Meso - <5 mm (granule size)
Micro - powdered (generally unseen).

The working group also made a list of some more common or important types to track. Suggested were:

Nets (by type)
Other fishing gear
Strapping bands (open/closed) (cut/uncut)
Granulated plastic (recycled plastic)
Particulate plastic
Fragmented plastic
Plastic bags
Plastic containers (country of origin, age)
Styrofoam
Medical waste
Rope
Entanglement remains (e.g., bones)

Due to the time limitation, the group was unable to decide on broad categories for use in comparing data on an international scale, but recommended a review of existing categories in order to develop a common list that could be tailored to fit individual areas of interest.

MONITORING PROGRAM

Also because of a time limitation, the working group did not address the topics of sampling frequency and sample size requirements. A seasonable variation in the amount of floating debris was noted.

PROCEDURES MANUAL

The working group generally agreed that a procedures manual detailing survey techniques should be written. This manual would provide ideas for those interested in initiating marine debris studies.

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REPORT OF THE WORKING GROUP ON ENTANGLEMENT OF MARINE LIFE

(William R. P. Bourne, Chair)

TERMS OF REFERENCE

It was reported at the first conference on marine debris in 1984 that individual seals, turtles, birds, and fish, some belonging to endangered species, become entangled at times in marine debris. The frequency and severity of these interactions were usually unknown, and no conclusive evidence was demonstrated for any effects on populations. This working group was asked to review the problem and identify the information needed to fill the gaps in current knowledge, notably by devising a model in the light of which current information could be assessed. This should include 1) age, 2) sex, 3) population, 4) numbers, 5) distribution, 6) legal status of victims, 7) activities and materials causing problems, 8) information that is needed to complete the picture and monitor its future development, and 9) the priority that should be given to different aspects of the investigations.

THE WORKING GROUP

The findings at the 1984 conference still seemed valid, so in order to avoid repeating preconceived ideas, the working group first considered materials which cause problems and their impact on different animals. The previous working group reports were then reviewed to see what progress has been made. The first conclusion is that, despite the accumulation of circumstantial evidence that marine debris may have an adverse effect on all sorts of marine wildlife (including cetaceans, which did not receive much attention previously), the information is still insufficient to show clearly the magnitude of the problem.

LIMITATIONS OF THE DATA

Care is needed in the interpretation of the available information. It is substantial only for the most common species of two out of the four main groups affected, pinnipeds and birds. These spend long periods on land at breeding sites, where they can be counted and marked. Even here information is deficient for the important period spent at sea. Much less is known about the turtles, which spend most of their time at sea, and the cetaceans, which never come ashore at all. Owing to the way in which the information is collected, it still remains difficult to distinguish between the effects of a variety of interacting factors. These include oceanic fluctuations, disturbance while breeding, the impact of fishing on both the animals and their food supply, disease, and pollution.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

THE NATURE OF THE PROBLEM

Human artifacts must have caused hazards for wildlife since man first went to sea. They cause two types of problem: killing animals in unpleasant ways, a problem whose nature is self-evident so it will not be discussed further here, and harming the status of species and ecosystems. Both uncontrolled hunting or fishing and the incidental capture of unintended animals while taking other species (by-catches) potentially cause conservation problems. Although such factors lie outside our terms of reference, it must be remembered that not only may the losses of marine animals from hunting and fishing be only a fraction of the losses from natural causes, but losses due to marine debris may also be only a fraction of those from hunting and fishing. In such cases, entanglement may be important as a separate entity only to man, because the animals that it kills are deducted from his catch. The situation starts to acquire a wider significance only when the mortality of any animal becomes large enough to affect the welfare of the species and the ecosystem as a whole as well.

Nets

In the past, netting was made of natural materials which were not very durable, so that lost nets were noticed to cause a problem only by fouling vessels. Following the introduction of nylon and other synthetic netting after World War II, there have been growing problems with both lost or abandoned nets and the fragments torn from them by obstructions, discarded during repairs, or used to make small traps which subsequently disintegrate. Some reference collections of different types of netting have been made in the hope of identifying their origin--for example, where strange net which presumably comes from the tropical Atlantic washes ashore in the West Indies. It was thought that it might be useful to consult the fishing industry about the preparation of a guide to different types of fishing gear and its likely origin.

It was considered whether nets should be constructed of, or fastened together with, more rapidly degradable material, so that they would break up and sink sooner when lost. However, it was thought that this would lead to the production of more small fragments of net on the sea floor and along the shore, which would add to the problem. Experiments suggest that, if left intact, whole nets tend to bunch up and may cause less problem for wildlife. Thus it may be better to try and keep the net in one piece so that it is more easily removed or immobilized. It has been reported that floats of unequal size drift at different rates with the wind and current, keeping the net open, so the effect of the buoys and weights used on the performance of nets may deserve more attention.

There still appears to be a need for further study of the way in which animals are caught in nets and the fate of lost nets, using marked trial specimens to see how long they continue ghost fishing at sea and whether they catch more or different animals as they come ashore.

Hooks and Line

These are one of the commoner agents ensnaring wildlife and, occasionally, people. Discarded angling gear often hooks or ensnares birds. Fishing has been banned from some North Sea oil platforms because lost gear has caused problems for divers. Here also the situation has been made worse by the adoption of durable nylon line. It seems likely that the longlines used at sea, which may extend for up to 96.5 km (60 mi), with several thousand hooks and few buoys, may present a more serious problem. Little appears to be known about this, and it deserves more study.

Loops, Sheets, and Sharp Objects

Other potentially dangerous objects may appear occasionally at sea. They range from wrecks and heavy machinery and construction material discarded by the oil industry, through nautical gear and packing materials and containers, to clothing and household equipment. It seems easier to consider the nature of the hazard that they present than the identity of the object concerned.

Anything which incorporates a loop or ring is potentially hazardous. This includes knotted rope, uncut packing bands, containers with holes, loose webbing or fabric, plastic sheeting, and, of course, netting. These present lethal threats to any marine animal up to the largest whale, should their head, jaws, or limbs become ensnared while hastily seizing mobile prey, or hunting and playing around drifting material. Such objects should be disposed of ashore or by incineration.

Anything which includes, or can break down to form, a sharp point or cutting edge also presents a hazard, especially if it is concealed among innocuous materials. Such objects include wrecks and dumped heavy equipment which may catch nets on the sea floor, lesser metalwork, woodwork with projecting nails, tins opened to leave sharp edges, and fragile glass containers. In addition to being a threat to wildlife, these are also a threat to people who are diving, hauling nets which have collected debris, or walking along the shore. All such objects should also be disposed of carefully.

It seems desirable to redesign some objects which regularly cause serious problems. These include perforated plastic six-pack yokes, cans which normally have sharp edges when opened, and openers which leave cans with sharp edges.

VULNERABLE ANIMALS

There is accumulating anecdotal evidence that virtually all marine animals are occasionally entangled in debris, but quantitative data are available for few of them. The main cases where it appears important follow.

Cetaceans

Entanglement appears to be unusual and to be reported most often among the smaller species which are found near the shore. Its impact might be most serious with the North Atlantic right whales, *Eubalaena glacialis*. This is a large whale population reduced to a remnant of a few hundred by commercial fishing which has failed to recover despite half a century of protection, and some are known to be entangled occasionally in nets (Report of the International Whaling Commission, Special Issue 10, p. 116-119, 1986). Nearly a third are also said to be scarred from unknown causes, which might include other whales (notably killer whales), rocks, collisions with ships, and fishing gear, since they frequent areas with concentrations of plankton and these areas are often important fisheries. It seems time that these whales received more study.

Phocid Seals

While these seals are occasionally entangled in netting, the incidence is not usually high. It appears to be worst in the endangered warm water monk seal, *Monachus* sp. The only surviving species in the Mediterranean and North Pacific are both reduced to hundreds. A number of Hawaiian monk seals, *M. schauinslandi*, are known to have been killed by net fragments along the shore, and nearly a quarter of the mortality reported in Greece was also found to be due to fishing gear (J. Jacobs and A. Panou, Conservation of the Mediterranean monk seal, *M. monachus*, in Kefalonia, Ithaca and Lefkada Islands, Ionian Sea, Greece, Institute of Zoology, University of Munich, Seidlstrasse 25, D-8000 Munchen 2, Federal Republic of Germany, 221 p., 1988, per D. E. Sergeant). These species clearly deserve more attention.

Otariid Seals

While many populations of these seals were reduced by exploitation for skins and oil in the past, most now appear to be recovering. Possibly owing to their large numbers, their tendency to feed in areas with important fisheries, and their active behavior and slender physiques, they are also among the marine mammals most prone to entanglement. Young animals which play around nets seem particularly vulnerable. While most species are maintaining their numbers, the northern fur seal, *Callorhinus ursinus*, has been declining in some areas in recent years. A number of other factors which are difficult to study, such as overfishing and climatic change, may also be involved. It seems desirable to continue monitoring the breeding populations, investigate the animals' movements and relationship to nets at sea, and compare the results with those for increasing populations.

Chelonians

Most of the turtles now appear to be endangered, but while they do become entangled occasionally, there appears to be no evidence that this is having any impact on their numbers comparable to such factors as overexploitation for shell, meat, and eggs, disturbance of the breeding

habitat, losses in fishing nets, and ingestion of plastic material. Pelagic ridley turtles, *Lepidochelys* sp., may be the most vulnerable. The depleted Kemp's ridley turtle, *L. kempi*, is confined to one breeding beach in the Caribbean; the olive ridley turtle, *L. olivacea*, has been found entangled in the Pacific.

Birds

Birds become entangled in nets, hooks and line, and other debris occasionally, and the reported incidence in British Trust for Ornithology (BTO) banding recoveries of the common guillemot or murre, *Uria aalge*, has increased from 5% before 1970 to 37% since 1987 (C. Mead, BTO News 163, 1989). There is no evidence yet, however, that entanglement is having an important impact on bird numbers when compared with disturbance by man and introduced predators at the breeding places, or losses due to active fishing gear or oil pollution. Some species, especially the Pelecaniformes, are also vulnerable when, to make their nests, they collect floating material which may ensnare either the old birds or their young. The species for which there is the most evidence of damage from pollution of all kinds, the northern gannet, *Sula bassana*, is nonetheless increasing explosively in most areas, even at a small colony on Flamborough Head, England, where more than half the nest material is composed to nylon netting, and where many birds also become entangled at sea.

Fish and Shellfish

While other marine animals may become entangled in debris occasionally, there is no evidence that the resulting mortality amounts to more than a small fraction of that due to fishing. Debris-related mortality therefore seems most important as a loss from fisheries, as discussed by the working group on ghost fishing.

PRIORITIES

The group was asked to arrange its recommendations in order of their importance. Of highest priority is the collection of more information, arranged to cover as many areas and aspects of the subject as possible. There are still many important gaps in the available information, including several inadequately studied major groups of animals where the losses may be important, such as the cetaceans, sirenians, and chelonians. There are also several inadequately studied potential problems, such as longlines and sharp objects. A large part of the world is still inadequately covered--this conference has lacked any direct representation from not only the Communist and developing nations, but also South America and Australia.

Organization

It was thought that a more permanent organization is required to obtain information from more places. This should be composed of a limited number of representatives who are active in research on different animals, on different aspects of the problem, and in different areas. Its purpose

should be to expand the sphere of activity and maintain more continuity and consistency in recording methods. This would require the identification and enlistment of suitable people, whether in government organizations with their own resources, or voluntary bodies. Providing limited help with administrative expenses and the cost of attending meetings would be useful.

Information

Even in areas where there is already an interest in problems caused by marine debris, there is still a need for more means of circulating information and advice. This could include such matters as the identification of the materials and species encountered, the examination of stranded animals, and the best ways to record comparable observations. It would be useful to have a simple field guide to introduce more people to the subject, supplemented with a newsletter to report further progress and results. (The Marine Pollution Bulletin would be happy to assist.)

Research and Conservation

For purposes of economy it seems desirable to devise proposals that will cover several objectives simultaneously. These should include as far as possible the most vulnerable species in each of the main groups of animals, the most sensitive areas, the most critical threats, and mitigating measures. Five projects which between them might cover most aspects of the subject are monk seals, fur seals, right whales, sea turtles, and man.

Monk Seals

The marine animal for which entanglement appears to pose the worst threat is the Hawaiian monk seal in the Northwestern Hawaiian Islands (NWHI), where several are known to have died as a result of entanglement in stray fragments of net along the shore and where there appears the best chance of practical action to alleviate the threat of entanglement. This area is also important in several other respects. It is one of the first nature reserves of international importance. In addition to studying the impact of entanglement on this most vulnerable phocid seal, investigations there could also cover the impact of debris on a variety of other wildlife, including entanglement of sea turtles and ingestion by albatrosses and other seabirds, in a remote situation in the tropical Pacific. Measures should include the regular collection, evaluation, and destruction of debris on both the beaches and outlying reefs, the liberation of all live entangled animals, and studies of dead ones. The situation of the even rarer Mediterranean monk seal also needs further study, which could also be integrated with a study of related issues in a much more heavily developed area.

Fur Seals

The other marine animal where there is already evidence of serious mortality from entanglement is the northern fur seal. It also inhabits

established nature reserves of international importance. The recovery of its original vast numbers was previously a cause for general satisfaction, and any continuation of its recent decline would cause wide concern. It differs from the preceding species in its more migratory behavior, and may be encountering its most serious problems at sea away from the breeding places. At present it still has a much larger population than the endangered phocids, representing the other main group of otariid seals, so it can be studied more actively with less risk of serious disturbance and might provide interesting comparative results. It is important to continue monitoring the breeding populations, and investigations should be extended out to sea on a larger scale, both tracking animals on their feeding movements and migrations (notably by satellites), and studying their reaction to nets at sea. Such investigations should also yield useful general information about the welfare of other wildlife and the impact of marine debris further north in the Pacific.

Right Whales

The cetaceans for which there is possibly most cause for concern are the North Atlantic right whales (though most right whale stocks are depleted). These provide an instructive contrast to the previous species, since they are much larger, yet feed on plankton in an area with active fisheries in another ocean. Although they were originally very numerous, they were the first species seriously reduced by modern whalers and have failed to recover after half a century of protection. A certain amount is already known about them, such as the location of a small population with many scarred individuals, some of which are occasionally killed in nets. Humpback whales are regularly caught (and sometimes killed) in coastal nets in the same area, so the right whales may be encountering similar problems out at sea. It therefore seems desirable to learn more about the extent to which entanglement is a problem for this species. This might also reveal useful general information about the impact of marine debris on the most important fishing grounds in the northern Atlantic.

Sea Turtles

It is doubtful that entanglement is as important a cause of mortality for turtles as ingestion of debris, and it might be better to investigate the two problems together. One approach might be to study the behavior of turtles in captivity when confronted experimentally with debris. It might also be useful to try to trace individuals from satellites. The most vulnerable species, which might merit attention at an early stage, appear to be the ridley turtles. Any investigation of Kemp's ridley turtle might also yield useful general information about debris-related problems in the Caribbean. It might also be possible to integrate any investigation of the green turtle with research on the Hawaiian monk seal to obtain a better picture of events at sea in actively exploited tropical waters.

Man

It is surprising that there seems to have been little attention paid to the animal whose welfare is of the widest general interest. A certain

amount of harm must be caused to people by marine debris such as netting, hooks, lines, and sharp objects. It seems time for an assessment of the risks posed by various categories of debris on beaches, in shallow waters, and brought up by trawls. It might prove instructive to carry out a trial survey among medical personnel, sailors, fishermen, and divers to discover whether they can supply any information about the incidence, nature, and cost of human injuries due to marine debris. It is possible that marine debris may also cause occasional human fatalities, either directly or by disabling boats, and if so it seems desirable to assess their frequency.

RECOMMENDATIONS

Specific recommendations included:

- Continued monitoring, removal, and destruction of lost or discarded nets and other debris presenting a hazard to monk seals, green turtles, and other wildlife in the NWHI, extending the work to the outlying reefs.

- Continued monitoring of the numbers, survival, breeding success, and incidence of entanglement of northern fur seals, extending the observations out to sea.

- Investigation of the impact of entanglement and other possible hazards on right whales in the northwest Atlantic and Kemp's ridley turtles in the Caribbean.

- A review of the long-term evidence for entanglement provided by bird banding and beach surveys.

- A survey of the injuries caused to man by marine debris.

- Observations of the movements and behavior of seals and turtles at sea using satellites.

- Collection of more information about net use and losses, and means of identifying the origin of different types of net.

- Studies of the movements and fate of marked debris, including nets, with further observations of the way in which animals react to debris at sea.

- Reviews of experience with voluntary beach cleaning, artificial reefs, and material left on the sea floor by the oil industry.

- The use of models to determine the population dynamics of different animals, the way in which processes affecting them are likely to operate, and the best data to collect to elucidate them.

- The formulation of standard recording techniques for different types of debris and victims of entanglement in order to facilitate the more systematic collection of records of entangled animals and fouled vessels.

- The preparation of a guide to types of lost or discarded nets and other debris, and the best ways to examine and treat entangled animals and record observations.

- The dissemination of warning against the particular hazards posed by rings and loops, especially uncut packing bands.

- The redesign of six-pack can yokes, so that they are broken up in use, and methods of opening cans, so that they do not leave sharp edges.

- It was concluded that, in view of the number of problems that require investigation and the wide area that needs to be covered, there is a growing need for the establishment of a representative international organization to coordinate the systematic collection and circulation of information about the occurrence and impact of artificial marine debris and possible conservation measures to mitigate its ill effects.

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REPORT OF THE WORKING GROUP ON GHOST FISHING

(Paul A. Breen, Chair)

OVERVIEW

Ghost fishing is a potentially serious problem because of the very large volumes of fishing gear now in use. Only a small percentage of this gear lost annually would amount to a very large loss. The increasing use of nondegradable materials such as plastic, vinyl-coated wire, and fiberglass means that lost fishing gear may persist in the marine environment for a long time.

Of the many gear types in use worldwide, the working group considered traps and gillnets to be of primary interest. Ghost fishing is well documented in coastal gillnets and in a few studied trap fisheries; it is much less well documented in pelagic gillnet fisheries. For most trap fisheries, no directed work has been done and whether ghost fishing takes place is not known. Much more work is required to study ghost fishing in specific trap fisheries and in pelagic gillnet fisheries.

Trawls and longline gear types probably cause smaller ghost fishing problems than do traps and gillnets. For other gear types, no evidence exists that ghost fishing takes place.

For American lobsters, the estimated economic waste is several million dollars annually. In other trap fisheries where it has been measured, the loss to ghost fishing appears to be a significant percentage of the reported catch. It seems certain that if other trap fisheries were examined further, serious ghost fishing situations would be discovered.

Mitigation of ghost fishing is technologically simple for traps, but requires situation-specific materials research, legislation, and industry education. Mitigation of ghost fishing by nets is more difficult. Both timed-failure devices and degradable meshes should be developed and tested for nets.

The lower priority problems of ghost fishing by trawls and longlines are poorly documented.

GEAR TYPES

The working group reviewed the various gear types in use with respect to their potential for ghost fishing. Traps, tangle nets, and pelagic gillnets were considered to have the highest potential for ghost fishing because of their passive mode of fishing and the very large quantities

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presently in use. Bottom trawls and coastal gillnets were considered to have the next priority. Longlines, both benthic and demersal, and lures were considered at a third level of importance.

With the many other gear types in use, the working group has no reason to suspect significant ghost fishing problems.

FRAMEWORK

The working group devised the following framework for summarizing and evaluating the existing information on ghost fishing impacts. The following questions apply to each species, gear type, and location problem. The working group recognized dangers in generalizing or extrapolating from one species or trap type to another.

- Does ghost fishing take place in a particular situation; i.e., for a particular species/gear type/location combination?
- At what rate does lost gear catch and kill target and nontarget species?
- How is gear lost?
- At what rate is gear lost, or alternatively, how much lost gear is there?
- At what rate does lost gear cease to fish?
- What actions have been taken to reduce gear loss?
- What actions have been taken to reduce the ghost fishing life span of fishing gear?
- What actions have been taken to enhance the recovery of lost gear?

ANALYSIS

The working group reviewed the existing data and analyses by gear type in the context of the framework devised. The analysis is presented in the format outline above. Further information on traps and gillnets can be found in the review by Breen (1990 [this document]).

Traps

Does Ghost Fishing Take Place?

Ghost fishing has been documented in traps in the fisheries for American lobster and Dungeness crab through simulated lost trap studies. For the Western Australian snapper fishery, ghost fishing is suggested by a preliminary lost trap study. Ghost fishing seems likely from observations in fisheries for king crabs, snow crabs, and Pacific sablefish.

Observations and short-term escapements have been used by some workers to suggest that ghost fishing does not occur, for instance in Western Australian snapper. However, the working group considers the published evidence inadequate to reject the hypothesis that lost traps ghost fish for any species.

For most of the world's trap fisheries, the question of ghost fishing is not addressed by published reports. From studies of the few species so far examined, it seems likely that many more trap fisheries suffer from ghost fishing.

At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?

The rate of capture by lost gear has been measured in American lobsters at 10% of the catch rate by the commercial fishery. For Dungeness crabs in a sheltered British Columbia bay, lost traps killed 10 crabs per trap year. For Atlantic snow crabs, a lost trap fishes only for the life of the bait, then stops fishing. No capture rate estimates are available for other species.

How Is Gear Lost?

Trap gear is lost in a myriad of ways. Vessel traffic and tow boating sever buoylines or drag traps into deep water. Buoylines chafe and break. Buoys may become detached, or can be attacked by marine birds or mammals.

Storms and strong currents may "drown" traps. Traps may be snagged on rocky bottom. Traps are carried away by trawlers or gillnetters. Buoylines are cut by vandals or in fishing disputes.

At What Rate Is Gear Lost, or How Much Lost Gear Is There?

Estimates of annual trap loss rates vary from 5 to 30% based on estimates made from surveys of fishermen (see Breen 1990). For Dungeness crabs annual estimates vary from 11 to 18%. These rates are probably typical of most trap fisheries. In two surveys of Dungeness crab fishermen, it was estimated that about 50% of lost traps continue to ghost fish.

In the Alaska king crab fishery, it is estimated that 30,000 lost traps remain on the fishing grounds. In the U.S. portion of the American lobster fishery, it was conservatively estimated in 1978 that 187,000 traps could be ghost fishing.

No estimates are available for other trap fisheries.

At What Rate Does Lost Gear Cease to Fish?

Traps without timed-failure devices might ghost fish for years. Treated wooden lobster traps may last 2 years; metal king crab traps may last 10-15 years. No experimental results are available.

What Actions Have Been Taken to Reduce Gear Loss?

To reduce trap loss rates, some jurisdictions have regulations that require traps to be buoyed with marked buoys. In some areas, seasonal and area closures create temporal or spatial separation of trap and other fisheries. In Washington State, buoys must be foam-filled and buoylines weighted to prevent losses from buoys sinking or vessels running over buoylines. In Washington State, trap fishermen are notified of potential gear conflicts. High technology navigation systems allow trap gear to be relocated with more precision. Educational programs have reduced gear loss.

All these actions are taken from American lobster and Pacific west coast jurisdictions. Apart from buoyage and marking requirements, little is known about actions to reduce trap loss in fisheries outside North America.

What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?

Devices to reduce the ghost fishing life span of a trap are required in all traps in Alaska, Washington, Oregon, and California; in Pacific sablefish traps in Canada; and in American lobster traps in Connecticut.

Actions taken to prevent ghost fishing outside North America have not been published.

What Actions Have Been Taken to Enhance the Recovery of Lost Gear?

The working group is aware of no programs to recover lost traps, except that a small-scale commercial operation once operated in Canada to recover Dungeness crab traps. In Alaska, king crab traps caught by domestic trawlers are slashed before being discarded. Trap recovery is probably opportunistic.

Pelagic Gillnets

Does Ghost Fishing Take Place?

Ghost fishing in a pelagic salmon gillnet was reported in a lost net recovery, and ghost fishing was documented in a simulated lost net study.

At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?

In one experimental simulation of lost pelagic gillnets, two fish were caught by 1,500 m of net in the first 3 days.

How Is Gear Lost?

Pelagic gillnets may be lost when cut by vessel traffic, broken by storms or large marine mammals, or when the fishing vessel fails to relocate her gear.

At What Rate Is Gear Lost?

The rate of gillnet loss has been estimated in one study at 0.05% per set. This estimate, from the Japanese salmon mothership fishery, appears to be the only available estimate.

Density of lost gillnet fragments observed from passing vessels has been estimated in several studies presented at this conference.

At What Rate Does Lost Gear Cease to Fish?

Two studies suggest that nets less than 2 km long fish for only a short time after loss and then rapidly aggregate into a solid mass. The net tends to remain open longer when attached to a large buoy.

What Actions Have Been Taken to Reduce Gear Loss?

Japan requires gillnets to carry radar reflectors at each end of the unit to prevent cutting by vessel traffic. Radio communication is used to direct vessel traffic around nets. To prevent loss in bad weather, shorter sets are made. Japan requires nets to be marked with radio transmitters, and old gillnets to be recycled. No information is available from other countries.

What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?

No actions have been developed to reduce the ghost fishing life span of a pelagic gillnet.

What Actions Have Been Taken to Enhance the Recovery of Lost Gear?

Japan requires nets to carry radio buoys and radar reflectors, and requires old nets to be recycled. Japanese research vessels pick up fishing debris.

Coastal Gillnets

Does Ghost Fishing Take Place?

Ghost fishing by Pacific salmon gillnets has been documented, and observations of ghost fishing by Pacific herring gillnets have been reported. Experimental results confirm ghost fishing in demersal gillnets in Newfoundland, New England, and New Zealand.

At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?

Catch rates of lost gillnets have not been estimated in any published study.

How Is Gear Lost?

Coastal gillnets are lost when nets become fouled on the bottom or on snags; broken by storms, marine mammals, or large fishes; cut by vessel traffic; or carried away by trawlers.

At What Rate Is Gear Lost?

Rates of gear loss for coastal gillnets are not immediately available. A submersible survey in a known area in New England found a density of 0.23 nets/ha. A Newfoundland study reports numbers of gillnets retrieved in direct retrieval operations.

At What Rate Does Lost Gear Cease to Fish?

Lost gillnets may become tangled (leadline over corkline) or balled up (tangled in the horizontal plane). Fouling increases visibility and reduces catches. No precise estimates of the rates of these processes are available. Ghost fishing has been observed in Pacific herring gillnets 7 years after net loss.

What Actions Have Been Taken to Reduce Gear Loss?

Most jurisdictions require proper marking and lighting of gillnets to prevent cutting by vessel traffic. Radar reflectors are required on gillnets in New England.

What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?

Recent New England experiments have examined degradable corklines and the effect of degradable panels along the net.

What Actions Have Been Taken to Enhance the Recovery of Lost Gear?

A Newfoundland program was conducted in 1975-76 to recover lost gillnets with specially designed recovery gear. In the British Columbia herring fishery, efforts are made to ensure that all gear has been recovered at the end of an open fishing period.

Bottom Trawls

Does Ghost Fishing Take Place?

Ghost fishing has been reported where trawl netting was stretched across bottom features or snags.

At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?

No estimates of catch rates by lost trawls are available.

How Is Gear Lost?

Trawls are lost when the net or doors become snagged on bottom obstructions. Snagging incidents may result in partial loss of the net. Trawls have been lost when fouled by submarines.

At What Rate Is Gear Lost?

No rates of trawl loss are immediately available. Some logbook programs may contain this information.

At What Rate Does Lost Gear Cease to Fish?

No information.

What Actions Have Been Taken to Reduce Gear Loss?

Snag charts reduce the incidence of net loss on wrecks or other obstructions. High technology navigation systems allow trawls to be set more accurately in known areas.

What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?

There appear to be no actions taken with respect to trawls.

What Actions Have Been Taken to Enhance the Recovery of Lost Gear?

The working group uncovered no information on this question.

Longlines

Does Ghost Fishing Take Place?

Pacific halibut are reported to strike and be caught on bare hooks. Lost halibut longlines may thus ghost fish.

At What Rate Does Lost Gear Catch and Kill Target and Nontarget Species?

No estimate of the rate of ghost fishing by longlines is available.

How Is Gear Lost?

Longlines are lost when snagged on bottom features.

At What Rate Is Gear Lost?

No estimates of loss rate or density of lost gear are immediately available. Some logbook programs may contain information.

At What Rate Does Lost Gear Cease to Fish?

There appears to be no information with respect to longlines.

What Actions Have Been Taken to Reduce Gear Loss?

There appears to be no information with respect to longlines.

What Actions Have Been Taken to Reduce the Ghost Fishing Life Span of Fishing Gear?

There appears to be no information with respect to longlines.

What Actions Have Been Taken to Enhance the Recovery of Lost Gear?

There appears to be no information with respect to longlines.

RECOMMENDATIONS

The working group made recommendations at three levels of priority: high, medium, and low. Within each level no attempt was made to assign priorities.

High Priority Recommendations

1. Fishery agencies responsible for trap and tangle net fisheries should conduct lost gear simulations to determine whether ghost fishing occurs and, if it does, the rate at which target and nontarget species are killed. If a ghost fishing problem is discovered, the rates of gear loss should be estimated through logbook programs or questionnaire surveys. In some situations, useful information might be obtained from surveys of fishing gear manufacturers.

2. Where ghost fishing has been demonstrated or is suspected in a trap fishery, the fishery agency should decide what timed-failure mechanism would be most appropriate to reduce the life span of traps and how soon to cause timed failure to happen. Research under actual fishing conditions should then be conducted to determine the most appropriate regulation for timed-failure devices. Industry should be consulted and involved in this research.

3. Further studies with simulated lost pelagic gillnets should be conducted. In order to simulate the loss of an entire net, studies should use nets approximating the length of commercial nets. More studies on smaller sections are also required. These studies should examine whether ghost fishing takes place and, if it does, then the rate of ghost fishing and the rate at which the nets form a tangled mass or otherwise cease to fish.

4. Direct observations should be made of lost pelagic gillnets to determine their shape and to determine the apparent rate at which ghost fishing for fish, birds, sea turtles, and marine mammals is taking place. These observations should be collated, made available, and distributed by a central agency such as the Food and Agriculture Organization of the United Nations.

Medium Priority Recommendations

1. Research should be continued and new programs developed to examine potential timed-failure mechanisms in gillnets and tangle nets. Both degradable net components and degradable mesh should be considered. In the former case, possible ghost fishing by sunken gillnets must be evaluated with appropriate experiments. In the latter case, the consequences of generating many small fragments must be examined. This research should also address the costs of timed-failure mechanisms for gillnets and tangle nets.

2. Fishery agencies should examine existing data or undertake new programs to estimate the rate of gear loss in fisheries using pelagic or coastal gillnets, trawls, or longlines.

3. Where ghost fishing has been demonstrated or is suspected with any gear type, the responsible fishery agencies should conduct research into the fishing life span of gear after loss.

4. In those fisheries for which an estimate of the impact of ghost fishing is available, ghost fishing should be examined as a mortality source in stock assessments and incorporated in fishery management plans.

5. In those jurisdictions where timed-failure devices are already required in traps, the rate of compliance with such regulations and attitudes of industry should be examined.

Low Priority Recommendations

1. Studies should examine whether ghost fishing takes place by longline gear, especially for Pacific halibut and tunas but also for other species as appropriate. If ghost fishing does occur, then studies should be conducted to measure the rate at which hooks of various kinds cease to catch fish.

2. Where it has not been done, charting of snags should be carried out to help vessels prevent net loss.

3. The possibility of encouraging or requiring vessels to retain recovered lost fishing gear for disposal on land should be explored.

4. Research should be initiated on possible positive effects of lost gear, especially lost traps acting as habitat for American lobster and floating masses of pelagic gillnet acting as fish aggregating devices.

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REPORT OF THE WORKING GROUP ON INGESTION

(Louis Sileo, Chair)

This report includes a summary of the information about ingested plastic presented during the technical sessions and a summary of the working group's discussions. Both are organized by taxa and deal with the prevalence and effects of ingested plastic.

SUMMARY OF TECHNICAL SESSIONS

Sixteen papers concerning ingestion of plastic were presented during the technical sessions. Five of these dealt with birds, two with fish, five with marine turtles, and four with marine mammals. There was one review paper for birds and one partial review each for fish and turtles. The majority (13) of the reports were of a descriptive or anecdotal nature. The latter are very useful for gathering baseline information for hypothesis generating and for defining and attracting attention to an emerging problem. Such anecdotal reports often show associations between observations, such as emaciation and the presence of plastics in stranded marine animal carcasses. However, with anecdotal data it is not possible to determine if such an association is coincidental or cause and effect. Only 4 of the 16 papers reported work with controlled experiments designed to test a hypothesis. There is need for more such studies designed to test hypotheses about the possible cause-effect nature of associations revealed by the anecdotal studies.

Most (14) of the papers presented information about the prevalence of ingested plastics: 9 papers introduced new data about the effects, usually harmful, of ingested plastic on individual animals. There were no data about those effects on the population dynamics of any species, nor about absorption of toxins from ingested plastics.

The nature and extent of the data presented in the technical sessions were summarized by taxa (Appendixes A to D); these summaries provided a basis for the working group's discussions. Crucial knowledge deficiencies were defined by the group and then given priority (Table 1). All priorities were reached by consensus. The areas of expertise of the scientists attending the working group sessions provided an equitable representation of the various taxa.

Future studies should have statistically adequate sampling schemes designed to test hypotheses that the prevalence is increasing or decreasing in given areas or taxa. Future studies of the effects of ingested plastics should also include statistically adequate experimental designs for testing

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In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Table 1.--Knowledge deficiencies and informational needs arranged in order of importance.

Priority	Information needed
First	Effects on marine turtles
Second	Effects on seabirds
Third	Prevalence in marine turtles
Third	Prevalence and effects on manatees
Fourth	Effects on large fish
Fourth	Prevalence in marine mammals
Low	Effects on larval fish
Low	Prevalence in fish
Low	Prevalence in seabirds
Low	Effects on marine mammals

hypotheses. It is possible that estimates of variance from studies already completed will provide the basis for determining sample sizes required for statistical significance in future studies.

Regardless of the taxon, the same three general pathophysiological effects were proposed: (1) mechanical blockages, (2) pseudosatiety, and (3) absorption of toxins from the plastic.

RESEARCH NEEDS

First Priority

Effects of Marine Turtles

Experimental feeding studies are needed to determine (1) diagnostic criteria for interpreting the lethality or other pathologic significance of loads of ingested plastic, and (2) the entire gamut of the pathophysiology of ingested plastic in turtles.

Justification

There are relatively few data available on the prevalence or effects of ingested plastic in turtles, but those data which do exist suggest that the prevalence is high and that ingested plastic causes significant lesions and mortality. The endangered status of marine turtles justifies a prompt look at the role of plastics in mortality. Finally, it seems that a favorable cost/benefit ratio might result from dollars invested in turtle research. So little is known that a relatively small sum may produce considerable new information.

Second Priority

Effects on Seabirds

Controlled experimental work is required to determine if (1) pseudo-satiety does occur, (2) the duration of retention and erosion rates of ingested plastics, and (3) the toxicity of ingested plastics. The results of such studies will establish the need for long-term population studies of things like the postfledgling effect of plastic loading of chicks.

Justification

The available data establish that frequency of ingestion is very high in some species of seabirds and that some individuals contain very large amounts of plastic. There are few data about the effects on individual birds or populations. The few data available show no cause for alarm, but if these preliminary data are misleading, the potential deleterious effects on seabird populations could be severe. Because of the ubiquity of ingested plastic in seabirds and the as-yet-unmeasured potential for harm, it is prudent to identify the effect. Also, this group includes several threatened or endangered surface-feeding seabirds including the short-tailed albatross, *Diomedea albatrus*, which may be at risk.

Third Priority

Prevalence in Marine Turtles

The working group recommends continued monitoring of the prevalence of ingested plastic and its association with lesions. The monitoring efforts should be improved to better determine how often it actually causes harm. The working group recommends that review of the Marine Animal Stranding network be conducted to determine if the network's activities could be enhanced by standardizing necropsy protocols and by including collection of data about ingested plastics. Adequate diagnostic pathology services should be provided for the biologists in the Network. Even though the anecdotal data generated by monitoring programs cannot prove cause-effect relationships, they do provide useful information data bases.

Justification

This is the same as for first priority. Also, the Marine Animal Stranding Network is already in place; it would seem cost efficient to strengthen the program and orient it to collect and analyze data on ingested plastics.

Prevalence and Effects in Manatees

The data presented in the technical session suggested that plastic ingestion is common and was considered the cause of death of one manatee. It is recommended that carcasses found through the Marine Animal Stranding

Network be examined to obtain as much information as possible from each animal recovered.

Justification

There are no data about the impact of ingested plastic on the manatee population. Since this is a remnant population near extinction, any avoidable source of death is unacceptable.

Fourth Priority

Effects on Fishes

The working group recommends that laboratory work be done first with large fish to determine under what conditions they ingest plastics and to determine further the effect of the plastics. For example, will ingested plastic be retained for long periods and cause gastrointestinal tract blockages? Will it induce pseudosatiety, or release toxic chemicals?

Justification

Potential losses to the commercial and recreational fisheries may occur if ingested plastics impair the health of large fish. The working group assigned fourth priority to this issue because field and laboratory evidence available to date are equivocal, and as yet there is no evidence of a significant problem.

Prevalence in Marine Mammals

The working group recommends that monitoring of ingested plastics in stranded marine mammals be continued and improved as much as possible, taking advantage of the Marine Animal Stranding Network.

Justification

The working group generally agreed that available data suggest ingested plastics are a lesser problem in marine mammals and that there are no apparent reasons to elevate this issue to a higher priority at this time. It was also stated that laboratory work might better elucidate the consequences of ingested plastics, but that laboratory work with marine mammals is impractical because of logistics and legal complications.

Low Priority

Low priority issues are not unimportant, but they are less pressing than those above.

Effects on Larval Fish

The working group recommends that additional laboratory feeding experiments be done with larval fish to determine if ingested microparticles reduce growth rates.

Prevalence in Fish

The working group recommends that a specific study be designed to look for plastics in the gastrointestinal tract of large, free-ranging fish and for indications that it causes harm. This might be accomplished by alerting and educating fisheries biologists about the issue. This work could be done in conjunction with other on-going studies.

Prevalence in Seabirds

The working group recommends continued monitoring for benefits accrued (public awareness, time-order trends), but suspects that monitoring will continue without specific, directed guidance.

Effects on Marine Mammals

Laboratory studies of the effects of ingested plastic would provide useful data, but the group generally agreed that such studies are impractical for logistical and legal reasons.

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APPENDIX A

Summary of information from five reports on the prevalence and effect of ingested plastics in seabirds.

Prevalence

Many previously unpublished data were presented at the technical sessions. Ingested plastics are present in many species and the prevalence is high in some species. Prevalence between species is influenced by feeding behavior, feeding location, season, year, resident or migrant status, and whether or not chicks are fed by regurgitation.

Effect of Ingested Plastic on Individual Seabirds

Some die from the lesions caused by impactions. Fledging weights of one species were reduced in chicks having high volumes of ingested plastic.

Effect of Ingested Plastic on Seabird Populations

There are no data available.

APPENDIX B

Summary of information from two reports on the prevalence and effect of ingested plastics in fish.

Prevalence

Ingestion does occur, but the information available suggests that this is uncommon. In one study, 20 of 3,000 larval fish contained ingested plastics. Nothing is known of the prevalence in large fish. In one study, most lancetfish contained one or more pieces of plastic.

Effect on Individual Fish

There is no clear evidence of an effect. In one study, larval fish ate 500 μ spherules, but there was no detectable short-term effect. No data are available about the effect on large fish.

Effect on Fish Populations

No data were presented.

APPENDIX C

Summary of information from five reports on the prevalence and effect of ingested plastics in marine turtles.

Prevalence

The few data available suggest the prevalence is high. In one study, 8 of 15 young pelagic turtles carcasses had intestinal compactions containing hundreds of pieces of debris. There were 3,000 pieces of plastic in 1 compaction. These compactions were the suspected cause of death. In another study, 60 of 111 beach-washed turtle carcasses contained intestinal debris, and 4 died from the effects. Yet another study reported debris in 12 of 168 stranded turtles; 5 of which had blocked pyloruses. Plastic bags or sheeting seemed to be the offenders.

Effect on Individual Turtles

Impactions can kill turtles. The few available data suggest that this is potentially a serious problem. Laboratory studies suggest that low doses of plastic have no effect.

Effect on Turtle Populations

There is no information available.

APPENDIX D

Summary of information from four reports on the prevalence and effect on ingested plastics in marine mammals.

Prevalence

The data are not completely clear. One report suggested the prevalence is low, others that it is high. Plastic was found in 15% of 63 dolphins and in 6 of 82 whales in one study. Another study reported that plastic debris was present in 67% of stranded whales. This study also reported debris in the stomachs of 23 of 86 Baird's beaked whales examined; 30% of this ingested debris was plastic.

Effects on Individual Marine Mammals

Data from both wild and aquarium specimens show that ingested debris can kill cetaceans.

Effects on Marine Mammal Populations

There are no data available.

REPORT OF THE WORKING GROUP ON ECONOMIC ASPECTS OF MARINE DEBRIS

(Kenneth E. McConnell, Chair)

The problem of marine debris is a classic example of markets failing to allocate resources efficiently. When firms and individuals use materials which escape into the marine environment, they impose costs on others. These costs--external costs, as they are known to economists--may be nonmarket, as in the aesthetic degradation of beaches or the killing of noncommercial species of birds and mammals. The external costs may also be incurred by market forces; for example, fishing vessels may have their propellers entangled in abandoned gear. Regardless of who suffers the external cost, its presence indicates a problem which requires some form of public policy to solve.

The marine debris problem is dominated by plastics and other nondegradable materials. Plastics have advantages in production and consumption processes that other materials lack. The replacement of plastics will therefore impose direct or inconvenience costs on consumers and producers. There are three basic ways to reduce marine debris: (1) reduce the loss and disposal of materials that may end up in the marine environment, (2) reduce the production of plastics and other nondegradable materials by using substitutes, and (3) engage in cleanup efforts.

Currently, knowledge of the economic aspects of marine debris is quite limited. This document outlines the basic economic issues and suggests research projects which would help in the process of reducing marine debris. The research projects can also serve as terms of reference for the economic issues of marine debris.

ECONOMIC COSTS

The economic costs of marine debris are the lost economic values that occur when the debris directly influences people and their behavior. These economic costs may be categorized as aesthetic, fouling of gear and vessels, and impact on fish stocks. Knowledge of these costs can help motivate government action. This requires information not only on the physical and biological effects of marine debris but also on the economic costs of these effects. The U.S. Office of Management and Budget, for example, is especially influenced by benefits and costs, not by physical effects. These economic effects require careful research because they do not show up in market transactions.

Aesthetics

Debris makes beaches less attractive. It traps fish and wildlife. Each of these entails an aesthetic loss to some individuals. Currently we

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

know practically nothing of the economic costs of either. We recommend two types of studies to help understand the magnitude of the economic costs of marine debris.

A Study of the Economic Costs of Debris on a Specific Set of Beaches

This study would pick a set of beaches and investigate the economic value of lost services that result from different levels of debris on the beach. The techniques for undertaking this research are well known to economists, but they have not been applied to marine debris.

A Study of the Economic Costs Incurred When Some Individuals of a Noncommercial Species (e.g., Birds, Mammals) Are Entangled in Marine Debris

Economists have some experience in estimating the loss in economic value from the threat of extinction of a noncommercial species but little or no experience when only a small number of the species are lost. This study would begin the investigation of this problem.

Fouling of Vessels and Fishing Gear

When vessels and their gear are impaired by contact with marine debris, there are two kinds of costs. The obvious cost is the repair or replacement cost for the damaged gear. Less obvious is the opportunity cost of the vessel and gear when it is not in productive service. Very little is known of this cost in the United States. There is evidence from Japan that the cost to fishing vessels is quite substantial. We suggest the following research.

Investigate the Incidence of Impairment and the Magnitude of Costs for One of the Following Industry Groups: Commercial Fishing, Shipping, or Recreational Boating

This research project would involve a small survey among owners or operators in one of these industry groups for a well-defined region.

Impact on Fish Stocks

The biggest impact of marine debris on fish stocks is ghost fishing. But there is also the possibility that consumers' perception of contamination of fish stocks by marine debris can influence the demand and price of selected fish products.

Ghost fishing

The nature of physical or biological effects of ghost fishing is well known, but the quantitative effects are hard to estimate. Ghost fishing has an economic cost in terms of the lost resource. We suggest gauging this cost with a joint project involving economists and biologists.

The Impact of Perceived Contamination on the Price of and Demand for Fish

A project which collects and describes incidence of market effects from perceived contamination would provide especially convincing evidence on the economic costs of marine debris. We suggest a survey of literature and of knowledgeable people to gather these incidents in the form of a research report. This evidence comes in the form of market price changes induced by perceived contamination.

POLICIES TO REDUCE MARINE DEBRIS

Economics, the study of choices and behavior, is sometimes useful, sometimes essential, in thinking about and designing policies to reduce marine debris. Research on the costs of reducing marine debris needs to investigate the direct costs of adopting different techniques, the demand for the use of nondegradable materials, and the rate of compliance with various regulations among different sectors of the public and industry.

Policies to reduce marine debris require people to change their behavior. Behavior can be changed through a variety of means: education, moral suasion, lobbying, incentives, and direct regulation.

Incentives

In 1987, 12 U.S. senators wrote to the President expressing their concern over the marine debris problem. They urged the study of various methods of reducing debris, including instituting deposits "and other incentives for retention and retrieval of debris." Incentive schemes may be especially cost-effective in controlling debris when education and moral suasion fail. The following projects investigate the use of fees and incentives as part of the solution. These projects are not listed in the order of priority.

Deposits on the Return of Nondegradable Products

The efficiency of deposits on beverage containers as a means of controlling land debris is well documented. This research project would investigate the potential for deposits for the return of plastic marine debris. It should focus on coastal states which have experience with deposit systems.

Fees on the Use of Nondegradable Materials

Business firms and households are good at allocating scarce resources when they pay for them. Fees on plastics would induce substitution of other materials. This project would investigate the feasibility of fees on potential debris in the marine environment.

Incentives at the Production Level

Debris in the marine environment is part of the larger social problem of solid-waste management. The disposal of nondegradables is a crucial component of this problem. Fees on the use of nondegradable raw materials, including plastic pellets, in the production process would guide producers to substitute other materials. Such fees would raise the relative costs of nondegradable materials and make it economically more attractive to develop degradable substitutes and to sponsor research in developing substitutes. This research should investigate the demand for raw materials at the production level and the potential for fees and incentives to spur the development of substitutes including recycled plastic materials.

Compliance

The typical approach to solving environmental problems is: to pass a law to prohibit behavior causing the problem, to devote a small amount of money to enforcing the law, and to engage in education and public awareness campaigns to persuade people to comply. This approach frequently fails, raising demands for more enforcement funds, harsher penalties, and so on. It may be fruitful to investigate alternatives to this traditional approach to compliance.

Investigate Alternatives to Traditional Methods of Compliance

Policies combining punishment and reward which partly subsidize the adoption of techniques to help people comply and impose clear penalties for the absence of compliance are used elsewhere. For example, sewage treatment has been enhanced by Federal subsidies to construct waste treatment plants linked to the requirement that all households hook up. Methods of linking compliance to rules and regulations for handling marine debris can be used to access to other beneficial programs. For example, the registration of boats might be linked to evidence that boats have systems for handling solid wastes. This research program would study compliance programs which include education, incentives, and penalties for a specific portion of the industry. The recreational boating industry is an especially good candidate for study because boating is so widespread and boaters so heterogeneous in attitudes.

Evaluate the Effectiveness of Moral Suasion Programs

Public campaigns to reduce pollution by moral suasion have been attempted for other forms of pollution. A study of these campaigns would help understand their failures, which have been many, and their successes, which have been few. This study should cover different countries and different times.

Onshore Disposal

The new laws require that vessels bring their nondegradable wastes to port. Ports are required to handle the solid waste. Within particular

regions, it may be economically very costly for all ports to handle all of the vessel-borne waste. We suggest the following research project.

Investigate the Economic Gains That Can Accrue to a Particular Region as a Consequence of Consolidating Waste Handling Facilities

Some ports are unable to handle wastes. Other ports may have excess capacity. An economic study of the costs of onshore waste handling would prepare ports for the resource demands and for setting port fees. When the costs differ among ports, there may be incentives to use different ports. Further, there are incentives to dump the trash if fees are based on the trash that is brought ashore.

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REPORT OF THE WORKING GROUP ON TECHNOLOGY

(William G. Gordon, Chair)

INTRODUCTION

The Working Group on Technology, while recognizing that further work is required to quantify the types and volumes of ship-generated debris, strongly believes that technology/methodology currently exists to address management of the majority of the wastes generated at sea. The group recognizes that a considerable portion of debris originates from such terrestrial sources as careless transportation of garbage, combined storm/sewage outfalls, storm and street drains, industrial activities, beach-goers, and at-sea disposal, and that management of these sources requires application of somewhat different technologies and methodologies. However, a large measure of the ship-generated debris ultimately will be transported ashore. Thus, satisfactory resolution of much of the marine debris issue will require rational resolution of many of the terrestrial waste management issues and problems.

SHIP-GENERATED DEBRIS

Ship-generated debris and sources are categorized in Table 1, Sources and types of ship-generated debris.

SHIP WASTE MANAGEMENT

Technology and/or methodologies for dealing with ship-generated wastes, and their potential application, are shown in the Table 2, available technology and methodology for handling ship-generated waste.

As displayed above, there are currently available a number of techniques for addressing ship-generated wastes. However, all ultimately require some degree of transportation of the waste ashore for disposition. On-land facilities for handling such wastes may not exist, and thus at-sea disposition will continue.

The group stressed that there is no single methodology or technology which will resolve the issue. Regardless of the size of the vessel or craft, a variety of practices will undoubtedly be employed. Brief descriptions follow.

Source Reduction

Source reduction is the use of materials on board the vessels which will reduce both quantity and volume of waste. Such practices will vary with segments of the industry and should be encouraged for all.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Table 1.--Sources and types of ship-generated debris.

Sources	Clean plastic	Contaminated plastic	Fishing gear	Paper	Metal and glass	Oils	Food wastes
Merchant marine	Large	Small	--	Medium	Small	Large	Small
Naval vessels	Large	Large	--	Large	Large	Medium	Large
Commercial fishing	Small	Medium	Large	Small	Small	Medium	Small
Recreational craft	Medium	Large	Small	Small	Medium	Small	Medium
Cruise ships	Large	Large	--	Large	Large	Medium	Large
Oil and gas operations	Large	Large	--	Large	Large	Large	Large

Alternate Materials

The use of alternative materials is a simple but effective strategy for plastic waste management at sea. This may involve the replacement of a given plastic product with either a different plastic product or a nonplastic product which is more disposable. This simple approach can have a significant impact on solid waste management options for shipboard use.

Effectiveness and feasibility of incineration of waste on board a vessel can be increased by the selection of plastics which can be safely burned for use at sea. Exclusion of chlorine-containing plastics and, perhaps, the use of compounds with high factions of fillers (to reduce BTU's per pound) are possible examples.

Recycling of plastics carried to shore is viewed as a plausible means of disposal. Plastics to be used aboard vessels might then be selected to ensure optimum blend compatibility of the disposed plastic waste stream. Alternatively, the plastics can be coded to allow easy separation into the different chemical types. Replacement of nonrecyclable material such as glass and metal (usually disposed of at sea) with recyclable material such as paper and plastic is also feasible.

Reducing the plastic content of a given product can lean to substantial improvements in disposability with minimal loss of performance. Plastic films, plates, and cups, for instance, can be replaced with plastic-coated or composite materials that are more disposable. At the extreme is the replacement of plastics and glass with paper, which can be more easily

Table 2.--Available technology and methodology of disposition of debris generated at sea.

Type of debris	Type of disposal							
	Incineration	Disposal at sea	Separation	Compaction	Recycle	Degradation	Alternate	Source reduction
Plastic	X	--	X	X	X	X	X	X
Foamed plastic	X	--	X	X	--	--	X	X
Fishing gear	X	--	X	--	X	--	--	X
Paper	X	X	X	X	X	--	--	X
Metal and glass	--	X	X	X	X	--	X	X
Oils	X	X	X	--	X	--	--	--
Food wastes	X	X	X	X	--	--	--	--

disposed of. In doing so, of course, the economic factors must be taken into account to make sure that the proposed substitution of materials is realistic. Substitution of materials that are easily compacted and stored on board is stressed by the working group.

Degradation

Deep-sea disposal of many materials remains acceptable. Waste food biodegrades, paper (unless plastic-coated) degrades, metal cans (if punctured) sink, and glass bottles (if broken or if caps are removed) sink. However, plastic materials regardless of form cannot be dealt with in this way as their rate of degradation is unacceptable for at-sea disposal.

Some common plastic and fibers can be made to photooxidize and biodegrade in a controlled fashion. In both film and fiber forms they are already in use in agriculture and some packaging applications. Olefins are among those polymers which can be engineered to degrade. Nylon and polyesters presently available do not degrade in an acceptable time. Nylon can be made to photodegrade, but photodegradable nylon is not yet commercially available. The products of degradation of most polymers are environmentally innocuous.

Photodegradable plastics are compatible with other technologies. Degradable plastics can be burned normally or can be recycled to secondary products. Degradable products can cause environmental problems in landfills, as many cease to degrade under anaerobic conditions.

Degradable plastics have potential disadvantages. For example, few of the existing degradable materials have been cleared by the Food and Drug Administration for contact with food. Some degradable plastics perform differently on land than in the marine environment, and require further evolution. Thus, industry is not yet prepared to supply economically feasible plastics which can be counted on for degradability at sea.

Recycling

Recycling of plastics is a process by which used plastic objects are collected, identified, separated (if necessary), and melt-processed into useful items. Recycling of plastic soda bottles, fishing nets, and general plastics waste is currently being done on a commercial basis. At present, probably less than 10% by weight of the annual production of plastics is being recycled. The impetus brought about by factors such as the increasing costs of dumping at landfills, the influence of environmentally concerned groups, the inherent value of the plastics themselves, which continue to increase in cost, and the profit motive for value-added products made of recycled plastics could well increase the use of recycling to as much as 50% of yearly production.

Except perhaps aboard very large vessels, recycling at sea does not appear to be a viable solution for dealing with plastics waste. A more practical approach is the establishment of recycling centers at ports receiving large volumes of plastic debris. Unless information on how much, what type, and when will it be landed is made available, industry is

unlikely to move. Accordingly there is a need to acquire much more information on the issue in order to encourage the private sector toward a positive response.

Another aspect of recycling is the reuse of plastic items for different purposes. An example of this is the use of fishing nets for decorative or recreational applications.

Recycling of various plastics together (commingling) will result in some difficulties. Commingling will reduce the value of the resultant product as it results in characteristics that are less desirable to most users. This problem must be addressed, particularly in view of the move toward laminated products of various plastics.

Compaction

Compaction technology as wide application for resolution of waste issues within the maritime industry. For many, compaction may be the most appropriate, as all solid waste may be reduced through compaction and stored readily aboard those craft where trips are of short duration. This would include virtually all recreational boats, coastal commercial fishery operations, and coastal maritime shippers. Obviously, on-land disposal must be economical and efficient in order to encourage the practice.

For recreational and small fishing vessels, the initial problem created by the need to retain all wastes aboard ship is that none of these vessels are designed with waste retention compartments. However, they are designed with water and fuel tanks, sleeping compartments, cargo and provision compartments, and most recently with sewage holding tanks. These vessels are designed with these various compartments because either laws require them or they are necessary for the operation of the vessel. Therefore, in a way similar to sewage holding tanks, waste retention compartments could become a necessary requirement of all vessels.

One suggestion for a type of shipboard waste retention compartment might be a "shipboard waste compactor." One could be designed to run off the ship electrical system or be hand-operated. If owner-installation were possible, then some of the burden of cost to the vessel owner would be lessened. Such a device could provide for improved sanitation as well as make transfer of wastes easier. For example, the ports could store compacted wastes more neatly and securely than "untreated wastes," which are often unsightly, cause odors, and are cumbersome to store.

Separation

Separation of all wastes by type will become part of all successful waste management practices within the maritime industries. This methodology must be fully integrated into customary practice in combination with others. All practices must be at reasonable cost and effective.

Combustion

Combustion includes low technology burning and incineration.

Low Technology Burning (e.g., Use of Burners)

Low technology burning has important practicabilities and benefits:

1. It can be an attractive option for compliance with Annex V.
2. It is low in cost.
3. It needs relatively little deck space.

It also has some potential pitfalls:

1. Some separation of hazardous materials is necessary.
2. Products of incomplete combustion (e.g., dioxin, furans) of a wide range of materials (including salt from the marine environment) are environmentally hazardous. Potential hazards include toxic air emissions.
3. There are current problems concerning disposal of toxic ash (which may be resolved in the near future as a result of manufacturing modifications by the plastics industry).
4. The regulatory climate concerning air pollution emissions could change in the future.

Incineration (e.g., Insulated Combustion Chambers With Mechanical Air Control)

Incineration also has important practical aspects and benefits:

1. It is an attractive option for compliance with Annex V for ships such as cruise ships, merchant vessels, and tankers.
2. It provides operational flexibility, given the variable availability of port reception facilities.

It, too, has potential pitfalls:

1. Trained skilled personnel are necessary for proper operation.
2. It is more costly than low technology burning or overboard dumping.
3. Combustion of plastics, salt, and other materials produces air pollution emissions.
4. There are current problems concerning disposal of hazardous ash (which may be resolved in the future as a result of manufacturing changes).

5. Regulatory climate concerning air pollution emissions at sea could worsen in the future.

LAND DISPOSAL

The working group recognizes that ultimately ship-generated debris, particularly plastics, will be transported ashore for disposition. Land facilities, therefore, must be expanded or developed to accommodate the increased volume of such materials. Shoreside receivers must be cost effective and convenient in order to encourage maximum use. Shore-based industries should be encouraged to recycle such materials; they will require considerable information on the types, quantities, and location of the materials. Governments should implement policies and incentives permitting and encouraging such initiatives, but this, too, requires a much greater level of knowledge than is currently available.

The group stressed that marine debris is clearly linked to the land and that all efforts to encourage rational waste management must be extended globally.

RECOMMENDATIONS

Data

More information should be obtained about types, quantities, and distribution of the plastic materials which, under MARPOL regulations, will be brought ashore for disposal. Such information should be disseminated throughout the plastics industry to encourage reuse of such material.

Technology

Research and development of new technologies should be encouraged.

Low Technology Burning

1. Research on environmental impacts of air emissions.

2. Research and development of guidelines concerning materials separation and operations.

3. Research concerning environmental implications of ash and methods of disposal.

Incineration

1. Research on environmental impacts of air emissions.

2. Research concerning environmental implications of ash and methods of disposal.

3. Research concerning hydrogen chloride corrosion of incinerator units and accompanying potential effects on durability. Measures to address problems, if necessary.

Ship Design

1. New design should accommodate waste management strategies.

2. New construction should include facilities and space accommodations for waste management.

Plastics

1. Development or identification of the more desirable plastic mix streams for commingled plastics.

2. Development of performance standards for alternative materials used for specific product applications.

3. Development of trade-off studies on performance versus disposability.

Policy

No single methodology or technology will ensure compliance with waste management regulations. Accordingly, no policy should be established which prohibits technologies which have potential--keep all options open.

Governments should work together to create incentives for on-land disposal wherever feasible. Recycling, for example, will be feasible only where economic conditions are ideal for such practices. Governments should take the lead to assure that new and complementary technologies are created.

Education

Manufacturers of items such as packaging, fiber, and netting, are not aware of the capabilities and potential of programmable degradable plastics. Efforts should be undertaken to achieve broad dissemination of such information. The working group suggests that the plastics industry undertake such efforts.

There is need for a global network to disseminate information on the impact of marine debris widely and to uniformly encourage development of modern technologies or methodologies everywhere.

There is need for education throughout the private sector, aboard all classes of ships as well as shoreside, to encourage good waste management practices.

General Views

The working group strongly endorses the need to conduct global workshops on the issue of marine debris periodically. Sessions should include technical aspects of present and emerging technology for shipboard application. Invitees should include those potentially interested in land-based use of materials.

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REPORT OF THE WORKING GROUP ON LAW AND POLICY

(David Cottingham, Chair)

The working group reviewed existing legal and institutional arrangements to curtail the disposal and loss of solid wastes into the marine environment. Many nations have signed various international agreements and passed domestic laws that prohibit or limit disposal of plastic and other refuse into the sea, including disposal of wastes from ships. An undetermined, though probably significant, amount of marine debris originates on land. The group, therefore, concluded that solutions to the problem of marine debris should be developed and implemented in concert with efforts to address broader solid waste management issues. The most pressing needs identified include:

1. participating in the relevant international agreements;

2. assuring that adequate reception facilities are available at all ports and harbors to receive ship-generated garbage returned to shore; and

3. adopting national policies and programs, such as recycling and innovative packaging, to reduce the quantities of solid waste generated.

CONTROLLING AT-SEA SOURCES OF MARINE DEBRIS

The international agreement of greatest importance for controlling the discharge of plastics and other solid wastes into marine waters are:

- International Convention for the Prevention of Pollution from Ships, 1973/1978, Annex V (MARPOL Convention); and

- International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention (LDC)).

The MARPOL Annex V regulates the disposal of ship-generated garbage. The LDC restricts transporting land-generated solid wastes to sea for the purpose of dumping.

At least 10 regional conventions control various forms of marine pollution, including the disposal of plastics and other solid wastes, from both sea- and land-based sources. They include:

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- Convention on the Conservation of Antarctic Marine Living Resources, 1980.
- Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1974 (the Helsinki Convention).
- Convention for the Prevention of Marine Pollution from Land-Based Sources, 1970.
- International Convention for the High Seas Fisheries of the North Pacific Ocean, 1952.
- Convention for the Protection of Marine Pollution by Dumping from Ships and Aircraft, 1972 (the Oslo Convention).
- Convention for the Protection and Development of the Wider Caribbean Region, 1983 (the Cartagena Convention).
- Convention for the Protection of the Mediterranean Sea Against Pollution, 1976 (the Barcelona Convention).
- Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, 1978.
- Convention for Cooperation in the Protection and Development of the Marine Environment of the West and Central African Region, 1981 (the Abidjan Convention).
- Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment, 1982 (the Jeddah Regional Convention).

The latter five are part of the United Nations Environment Program Regional Seas Program.

The working group concluded that these international conventions jointly prohibit the disposal of plastics and other solid materials in the sea, thereby establishing this prohibition as "customary international law."

Of 131 nations that are members of the International Maritime Organization (IMO), 36 have ratified optional Annex V of MARPOL as of April 1989. These countries account for approximately 56% of the world's total gross commercial shipping tonnage. Many signatory nations are still in the process of developing programs to implement Annex V. In particular, many ports do not have adequate or convenient facilities for accepting ship-generated garbage.

Annex V identifies five "special areas"--the Baltic Sea, Red Sea, Mediterranean Sea, Black Sea, and "Gulfs Area." Within these special areas, ships are prohibited from disposing of all solid wastes (except comminuted food wastes beyond 12 nmi from shore). Before these provisions

can become effective, however, 1) each adjoining nation must certify that it agrees to designation of the area as a special area, and 2) that its ports have adequate reception facilities for handling ship-generated garbage. All nations surrounding the Baltic Sea have notified IMO. As of 1 October 1989, special area provisions in the Baltic Sea became effective. The Marine Environment Protection Committee (MEPC) recently added the North Sea as a special area. The United States is proposing to add the Gulf of Mexico as well.

CONTROLLING LAND-BASED SOURCES OF MARINE DEBRIS

Many items which become marine debris wash or blow into oceans and estuaries from landfills, municipal sewer systems, recreational beaches, industrial outfalls, illegal shoreline dumping, and other sources. Controlling land-based sources of persistent marine debris raises difficult problems which all nations must address domestically. International agreements are not well suited for controlling wastes from sites located on land.

Working group participants discussed the problems associated with effectively handling municipal and industrial solid waste throughout the world. Developed nations produce the largest per capita amounts of solid waste and generally have systems in place to dispose of it. Developing nations, on the other hand, frequently lack effective solid waste collection and disposal systems. Problems caused by marine debris in developing nations must be viewed within the context of their overall ability to handle all solid wastes. In such countries, marine debris may be a relatively small component of problems associated with handling solid wastes.

In the United States, responsibility for controlling nonhazardous wastes rests with the state and local governments. State and local agencies throughout the country have antilittering and dumping laws. However, enforcing these laws is difficult and penalties for violating them are not severe. Most local agencies, like the municipally operated Keep America Beautiful and Don't Mess With Texas programs, concentrate efforts on informing the public through antilitter campaigns.

Working group participants discussed the importance of reducing the volume of ship-generated solid waste by modifying ship stores purchasing and having rigorous onboard waste management. Current packaging systems often include throwaway containers, many of which could be recycled if systems and markets existed for the initial products and the recycled material. Japan, Denmark, parts of the United States and Canada, and other countries require people to separate newspapers, aluminum cans, clear and colored glass, and some plastic bottles for recycling. Seattle officials estimate that its recycling program, with curbside residential pickup of separated refuse, has reduced the volume of solid waste by 40%. Recycling has proven to be an effective way to remove aluminum and glass containers from the solid waste stream.

IMPROVED TECHNOLOGY

Although the subject of advanced technology was addressed by another working group, the Law and Policy Working Group briefly discussed ways to encourage research on degradability of single-use items such as plastic cups, plastic eating utensils, plastic bags, and tampon applicators. Degradable products may be a partial solution to the problem of marine debris. However, application of this technology requires further consideration of what happens to them as they break down. For example, wildlife may be just as likely to ingest the smaller fragments produced as plastic items degrade.

WORKING GROUP RECOMMENDATIONS

The Working Group on Law and Policy recommends that the following actions be taken by the IMO, national governments, and private industry:

Loss and Disposal of Garbage From Ships

1. Nations that have not yet ratified MARPOL Annex V and any regional conventions applicable to them which restrict disposal of solid wastes into marine waters should do so as soon as possible.

2. Nations which have ratified MARPOL Annex V should accelerate efforts towards full implementation of required provisions for port reception facilities.

3. The MEPC of IMO should review its guidelines for port reception facilities for garbage to facilitate effective implementation pursuant to Annex V of MARPOL. The MEPC should give particular attention to: 1) recovering or defraying the costs of operating port reception facilities and handling wastes (e.g., through recycling and refuse separation); 2) methods for handling various types of wastes; and 3) simplifying the steps and procedures that vessel owners and operators must follow to use port reception facilities.

4. The MEPC nations should consider measures which could ensure that vessels do not leave ports with garbage on board, for example, consistent fee systems.

5. National governments should provide information and, where possible, economic incentives to help ports comply with port reception facility requirements of Annex V. National governments also should assist local port communities where significant increases in the volume of solid waste result from the installation of new port reception facilities. For example, in the United States, Federal and state officials should expedite reviews of applications and permits for landfills and incinerators in port communities in developing

recycling programs, and expedite review of applications and permits for disposal facilities made necessary by increased wastes from ships.

6. Governments and port authorities should develop incentive systems, such as requiring or including off-loading fees as part of docking fees, rather than penalties to encourage compliance with Annex V.

7. The IMO should consider expanding Annex V guidelines or developing other forms of providing advice on the development and use of vessel logs for tracking the handling and disposal of ship-generated garbage.

8. Nations adjacent to special areas of Annex V should accelerate the development of port reception facilities to enable special area provisions to become effective at the earliest possible dates. In particular, nations bordering the Gulf of Mexico should take steps to designate the gulf as a special area under Annex V.

9. Governments should consider sharing collection and refuse transportation costs.

10. Governments should consider developing uniform signage and coloration standards for refuse and recycling facilities.

Shoreline Sources of Marine Debris

1. Nations should examine ways to prevent garbage and litter from escaping from landfills, industrial outfalls, sewage outfalls, and harbors or washing from beaches and shorelines into coastal waters.

2. Regional seas programs should provide technical assistance to member nations on siting disposal facilities and handling solid wastes in coastal areas.

3. Industries manufacturing or transporting plastics and plastic products should ensure that plastic resin pellets are not lost into the marine environment during handling.

4. All levels of governments should encourage recycling programs to reduce the volume of material which becomes solid waste. For instance, in Japan the plastics industry, in cooperation with fishing villages, has found ways to collect and recycle gillnets and trawl nets.

5. Governments should require that ships and barges transporting solid wastes be fully covered to prevent debris from dropping or blowing into waterways. Transfer facilities should be required to have booms and skimmers in

place to remove refuse which enters waterways, and load limits and maximum heights for barges should be prescribed.

6. The Environmental Protection Agency and coastal municipalities should consider developing and requiring installation of equipment to prevent items in combined sewer overflows from entering waterways.

7. National governments should require that governmental entities preferentially purchase recycled goods.

Compliance and Enforcement

1. Governments party to MARPOL Annex V should develop incentives to encourage vessel owners and operators to comply with garbage disposal provisions.

2. Vessel owners and operators should be encouraged to report to national authorities and IMO those ports and harbors in Annex V signatory nations that do not have adequate port reception facilities. They should also be encouraged to report ports in nations which are not party to Annex V. For example, in the United States, the U.S. Coast Guard should publicize citizen reporting networks and encourage Coast Guard Auxiliary members to report violations of marine pollution regulations, including the absence of required port reception facilities.

3. The IMO should encourage member nations to develop innovative enforcement policies, such as requiring ships to offload plastic refuse before they sail and providing inexpensive refuse removal.

Technology Improvements

1. National and local governments and private industry should develop institutional arrangements for recycling fishing nets and other large items that may potentially become marine debris.

2. Fisheries agencies should require time-release devices on crab, lobster, and fish traps and pots to avoid long-term ghost fishing by lost gear. Use of degradable material for selected components of drift net gillnets and other types of fishing gear should be required.

3. Private industries should conduct research on enhanced-degradable single-use plastic items such as cups, utensils, packing materials, and tampon applicators. The research also should examine by-products of degradable plastic materials and potential impacts on marine wildlife.

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REPORT OF THE WORKING GROUP ON MARINE DEBRIS EDUCATION

(Kathryn J. O'Hara, Chair)

Recognizing the difficulty of enforcing marine debris laws, especially at sea, education has been identified as an important way to help reduce the marine debris problem. Under the assumption that an informed public will be much less inclined to generate marine debris during both commercial and recreational activities, compliance with laws and regulations should be much higher. Education is particularly important in this issue because land-based sources of debris are primarily nonpoint, having diverse contributors that would be difficult to control under regulatory authorities alone. Moreover, longstanding, customary international law has permitted garbage discharge for ships in transit. Therefore, ethics and behavior patterns for individuals both on land and at sea must be changed, and education is the best known means for effecting such changes.

Charged with assembling a comprehensive list of the types of educational materials currently in use, the Working Group on Marine Debris Education identified more than 100 different types of educational materials. This included 21 brochures, 19 reports, factsheets and special documents, 11 posters, 10 videos, 9 curriculums and guides for educators, 6 newsletters, and more than 30 other types of educational materials ranging from public service advertisements to bumper stickers and coloring books. A complete listing of educational materials currently available may be obtained by contacting the National Oceanic and Atmospheric Administration's Marine Debris Information Office operated by the Center for Marine Conservation in Washington, D.C.

The working group was also charged with making recommendations for: (1) production of new educational materials and priority audiences for marine debris education, including the best means for delivery; (2) appropriate methods for the effective dissemination and utilization of these materials; (3) appropriate means for evaluating the success of educational programs; and (4) evaluation of lessons from the development of past marine debris educational programs and materials that may be of value in formulating environmental education programs in the future.

TYPES OF EDUCATIONAL PROGRAMS AND TARGET AUDIENCES

Marine debris education encompasses two key elements: The implementation of educational programs and the development of educational materials. With regard to the former, the group recommended that marine debris education should be incorporated into three primary types of programs:

1. formal education in a structured academic setting;

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

2. informal education outside a formal academic setting but within structured educational events such as adult education classes and organized youth groups; and

3. general public awareness.

Marine debris education has been or is presently being conducted for many groups, including: plastics manufacturers and processors, offshore oil and gas workers, commercial fishermen and processors, military personnel, politicians, solid waste managers, port and terminal operators, commercial shippers, teachers and educators, elementary, middle, and high school children, college students, recreational fishermen, recreational boaters, charter vessel operators, operators of cruise ships, cruise ship passengers, and the general public.

Several new groups would benefit from education and should be included in future efforts. These are the packaging industry; municipal sewage treatment operators; government officials; government enforcement agencies; coastal tourist industries; tackle manufacturers; operators of small ports, docks, marinas, and yacht clubs; suppliers of stores for vessels; boat manufacturers; employees of retail stores (including fast-food and convenience stores, and fishing and boating stores); environmental and conservation organizations; the media; employees of shipyards; longshoremen; and coastal hunters. Specialized efforts should be directed toward native and rural people.

Among all the groups identified above as target audiences for marine debris education, the working group concluded that five major groups are priority audiences:

1. all marine user groups;

2. the media;

3. teachers and educators;

4. school children; and the

5. general public.

A public awareness campaign is of utmost importance at the present time. Specific elements that should be addressed in developing this campaign are an initial assessment of human behavior and public perception of the marine debris problem. Using this information, a mass media public awareness campaign should then be developed. The working group felt that paramount to the success of this campaign is the development of a comprehensive strategy to use the media effectively as a tool to disseminate educational information. One suggestion was to solicit pro bono support from the National Advertising Council or a similar group. The working group also recognized that substantial funds are necessary to create this campaign.

EFFECTIVE DISSEMINATION AND UTILIZATION OF MATERIALS

After reviewing the list of marine debris educational materials, the working group concluded that there is a wealth of materials currently available but there is a need to facilitate the dissemination of these materials to appropriate groups. In 1988, the National Oceanic and Atmospheric Administration's Marine Entanglement Research Program established two Marine Debris Information Offices, which respond to requests for information on marine debris. The working group suggested that the dissemination of marine debris educational materials would be facilitated if the function of these offices were enhanced by increasing their visibility as an international resource center and providing them with sufficient quantities of educational materials to meet the demand. It was also suggested that an informational vehicle be established to provide updated information on the development of new educational materials and programs. There was an opinion, however, that educational materials should be disseminated in a more decentralized manner.

The dissemination of educational materials could be facilitated with assistance from established education organizations such as the National Marine Educators Association.

Existing government distribution mechanisms such as licensing and registration procedures for fishing and boating should also be used to disseminate materials.

The working group recognized the difficulty of disseminating educational materials on an international level due to the diversity of cultures and languages. However, it was suggested that specific international agencies such as the United Nations Environmental Programme, Food and Agriculture Organization, and the International Maritime Organization should be encouraged to take part in information exchange.

Efforts should be made to include the marine debris issue on the agendas of international conferences and meetings that address the issues of marine pollution and education.

EVALUATING THE SUCCESS OF EDUCATIONAL PROGRAMS

Evaluations could be conducted through long-term monitoring of beach debris and monitoring the usage of shoreside refuse reception facilities.

Formal surveys should be conducted, where possible, to assess changes in attitude and behavior.

LESSONS LEARNED FROM THE DEVELOPMENT OF PAST MARINE DEBRIS EDUCATIONAL PROGRAMS

Specific recommendations made with regard to development of educational programs and materials included:

- Involve members of the target audience in the development of educational materials and distribution.

- Identify specific discrete tasks for the involvement of individuals.
- Set realistic goals.
- Make educational experiences positive and enjoyable.
- Be familiar with the audience.

Other experiences shared by group members who have been involved in educational efforts pertained to the content of educational materials. This included the need to:

- Use good photographic materials that show the impact of debris.
- Personalize the message to specific target audiences.
- Emphasize the benefits to a group for their involvement in efforts to reduce the marine debris problem.
- Emphasize the importance of individual efforts.
- Emphasize economic impacts where appropriate.
- Keep the information as locally relevant as possible.
- Keep the message short.
- Highlight positive steps taken by groups or individuals to reduce the marine debris problem.
- Use facts that are updated and verified.

The working group suggested that researchers who are working on the issue of marine debris should be encouraged to make photographic materials available for educational efforts.

FORMULATING FUTURE ENVIRONMENTAL EDUCATION PROGRAMS

The working group also discussed the need to expand educational efforts to include the way in which debris affects estuaries and inland waters. There was considerable discussion with differences of opinion regarding the emphasis of marine debris educational materials and programs. The majority of participants agreed that the primary focus of marine debris educational materials should be to increase awareness of the problems caused by improper disposal of man-made wastes in marine areas. Others suggested that marine debris educational efforts should also emphasize the need for source reduction and the broader issues of wasteful consumer habits. It was agreed by all working group participants that the marine debris issue is part of the larger solid waste problem and, therefore, we should incorporate lessons learned from dealing with solid waste into marine debris education materials and programs.

The working group recognized that the marine debris issue has elicited an unprecedented emotional response and enthusiasm to take action. Therefore, the group sees great potential for using the marine debris issue as a stepping stone to encourage citizen involvement in other environmental issues.

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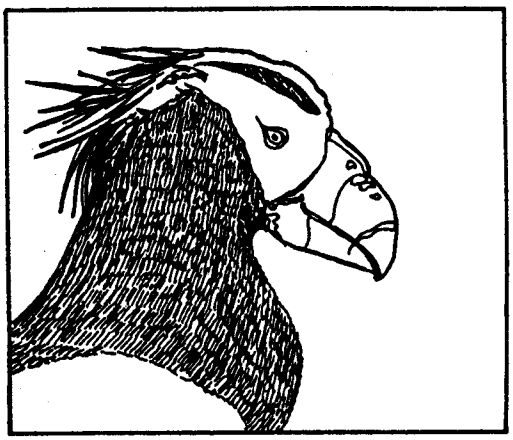

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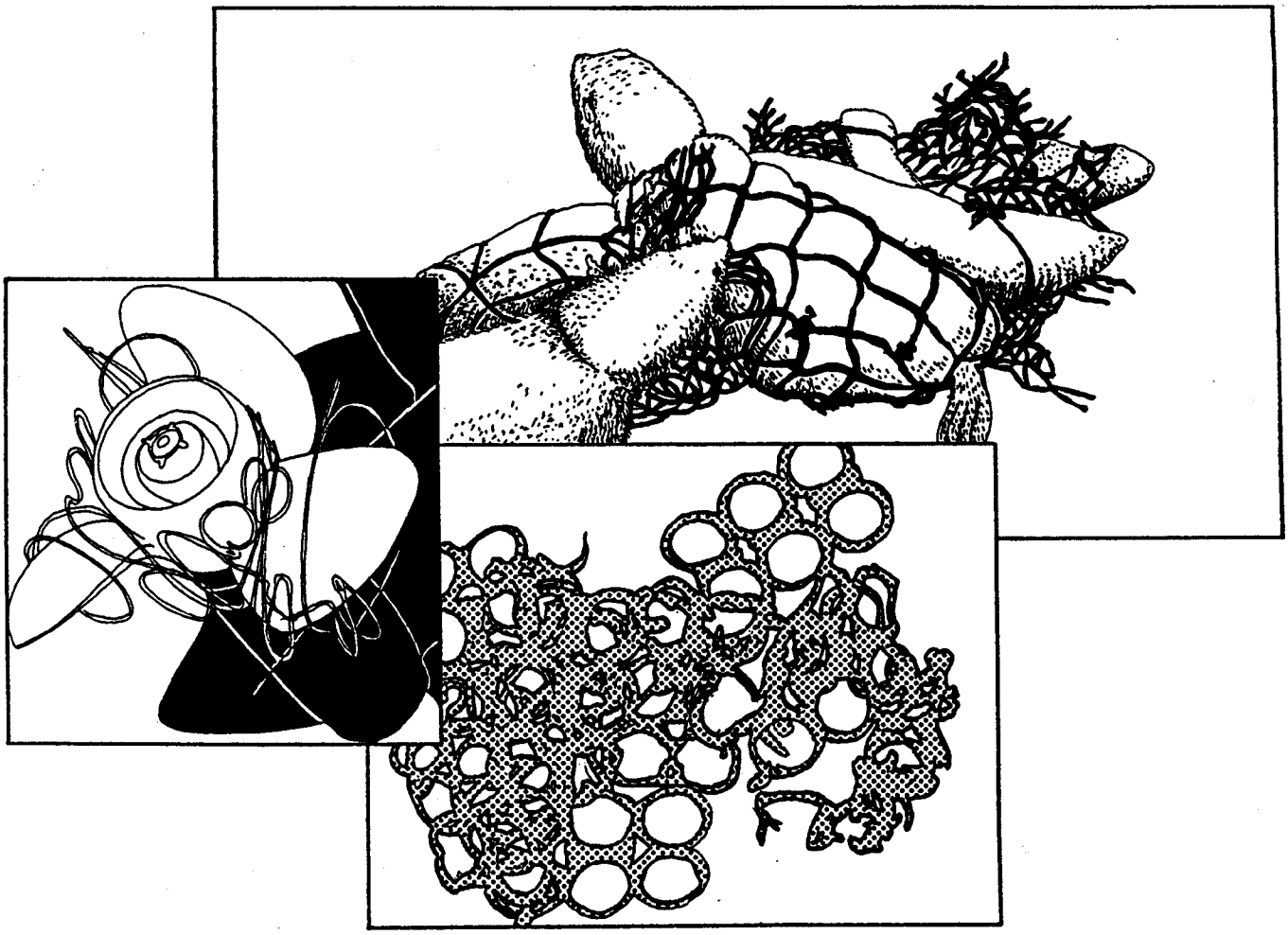

APPENDIX A

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APPENDIX B

AGENDA

1. Opening of the conference
2. Presentations
   a. Overview papers
   b. Session I - Amounts, types, distribution, and sources of marine debris
   c. Session II - Entanglement of marine life and ghost fishing
   d. Session III - Ingestion by marine life
   e. Session IV - Economic impacts on vessels and shorelines
   f. Session V - Solutions through technology
   g. Session VI - Solutions through law and policy
   h. Session VII - Solutions through education
   i. Poster presentations
   j. Video presentations
3. Working group meetings
4. Plenary session
5. Conference summary and closing

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